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Applying financial portfolio analysis to government program portfolios

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THESIS

APPLYING FINANCIAL PORTFOLIO ANALYSIS TO GOVERNMENT PROGRAM PORTFOLIOS

by

Bradford L. Botkin

June 2007

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Government agencies and the Department of Defense in particular, require decision-support tools when making funding decisions regarding portfolios of programs or projects. Government agencies have had some success in applying Project Portfolio Management (PPM) when choosing among potential programs; however, once programs are underway, financial managers routinely face funding optimization decisions similar to those of private-sector stock market portfolio managers. While private-sector portfolio managers rely on "stock-price" based financial portfolio analysis to aid decision making, government financial managers lack an equivalent "stock-price" metric for program or project performance. This research suggests the government's Earned Value Management System (EVMS) metrics may be used to generate a suitable proxy with which financial portfolio analysis can be conducted. From this analysis, risk and return trade-offs can be quantified and used when making portfolio decisions. An example using representative EVM data is presented. Recommendations on the possible applicability and limitations of the technique are discussed.

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APPLYING FINANCIAL PORTFOLIO ANALYSIS TO GOVERNMENT PROGRAM PORTFOLIOS

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ABSTRACT

Government agencies and the Department of Defense in particular, require decision-support tools when making funding decisions regarding portfolios of programs or projects. Government agencies have had some success in applying Project Portfolio Management (PPM) when choosing among potential programs; however, once programs are underway, financial managers routinely face funding optimization decisions similar to those of private-sector stock market portfolio managers. While private-sector portfolio managers rely on “stock-price” based financial portfolio analysis to aid decision making, government financial managers lack an equivalent “stock-price” metric for program or project performance. This research suggests the government’s Earned Value Management System (EVMS) metrics may be used to generate a suitable proxy with which financial portfolio analysis can be conducted. From this analysis, risk and return trade-offs can be quantified and used when making portfolio decisions. An example using representative EVM data is presented. Recommendations on the possible applicability and limitations of the technique are discussed.

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I. INTRODUCTION

A. PURPOSE

Recent initiatives within the Department of Defense (DoD) examine portfolio management as a potential tool to aid government managers in making both initial program capital investment decisions and in assessing the performance of ongoing programs. Private-sector stock fund managers have long used portfolio theory to construct and manage stock portfolios to meet investor risk and return goals. The use of portfolio theory would therefore appear to provide a well documented and rational, quantitative tool for government portfolio analysis. However, directly applying portfolio theory to government portfolios has been stymied by the lack of a suitable proxy for the private-sector "stock price" with which to perform the requisite calculations. Meanwhile, at the individual project (or program) level, government project managers often use Earned Value Management (EVM) data to evaluate, manage, and report the progress of their project. EVM data allow the project manager to quantitatively measure whether a project is on schedule and within budget. The coupling of EVM, with its potential to provide price proxy, with portfolio theory may provide a valuable tool for government portfolio analysis.

B. BACKGROUND

The concept of portfolio management has broad application and meaning within the federal government. By definition a portfolio is a grouping of objects with at least one common characteristic. This common characteristic links the portfolio's individual elements; tacitly acknowledging the key concept that the elements can be, to some degree, correlated with one another. Government portfolios tend to be arranged by: organization, resource, function, or phase. Examples of such groupings include: "Department of Energy projects," "military personnel," "flood control projects," and "systems procurement," respectively. Many government portfolios are combinations of the above. Within the

Department of the Navy (an organization), aircraft (a resource), may be grouped by procurement (a phase). Although government organizations routinely group assets and assign personnel to oversee them, referring to these groupings as "portfolios" is not common. Indeed, within the Department of the Navy, financial managers overseeing procurement, operations and maintenance, and ship construction accounts do not routinely perceive them as "portfolios."

For government financial management, most agencies and organizations create de-facto financial portfolios (such as the Department of the Navy example above) and assign a financial manager to orchestrate the flow of funds in and out of the portfolio. The financial manager works during the planning, programming, and budgeting process to ensure that budget requests are ultimately crafted that support both individual project or program goals and overarching fiscal guidance and constraints. During budget execution, the financial manager is routinely required to alter portfolio funding allocations due to unplanned costs or savings either within components of the portfolio, or because of emergent external requirements.

The challenges faced by portfolio managers are exemplified within the ongoing saga of the "federal Information Technology (IT) portfolio." [1] Over the past decade, federal IT allocations and expenditures have received a great deal of Congressional attention, highlighting the concept of portfolio-based decision-making. After watching aggregate federal IT expenditures skyrocket, Congress passed the Clinger-Cohen Act in 1996 requiring agencies to: better plan IT investments, link IT requirements with missions, and to institute consistent standards and policies to control and monitor IT investments (Powner, 2006)- in short, to develop a rational framework for IT funding decisions.

As the organization charged with overall budget responsibility, the Office of Budget and Management (OMB) began requiring that agencies account for the

[1] A significant issue was, and to a lesser extent continues to be, that there is no "federal IT portfolio." The federal government did not group or assign a manager to monitor aggregate federal IT spending. Government agencies or departments made independent IT funding requests, often with no agency "IT portfolio" or manager, either. Rather, each agency sub-unit established requirements and desired IT funding.

"risk" of their IT "portfolios." Specifically, the OMB now requires government agencies to report "high-risk" IT projects based on four criteria (Powner, 2006). If projects are deemed "high-risk," OMB requires agencies to report additional information. Of the 64 billion dollars budgeted for Fiscal Year 2007 IT expenditures, 226 IT programs totaling 6.4 billion dollars, or ten percent of all federal IT expenditures, are considered high risk (Powner, 2006).

While the OMB guidelines outline project management requirements- that clear requirements and a budget exist, that budget execution variances should be tracked, that duplication should be avoided, and that qualified management personnel should be assigned (Powner, 2006), the guidelines do not address how an agency IT portfolio manager is to make decisions among the various IT projects within the portfolio. If a project has been identified as high risk and fails to meet its cost or schedule goals, should funding be reduced, increased, or left the same? If a project is high risk and over-budget, should other IT projects be trimmed to provide the required funds?

C. RESEARCH QUESTION

This research will examine whether the use of EVM data in accordance with current portfolio theory might prove a valuable additional tool for managing a portfolio's risk and return. In support of this examination, this research will question:

- How portfolio funding decisions are currently made?
- Whether Earned Value Data is a suitable price "proxy"?
- How Portfolio analysis might be practically implemented

D. BENEFITS

This research aims to give mid-to-high-level government financial portfolio managers an additional tool with which to analyze the financial aspects of their portfolios, both suggesting and supporting rational, quantitative reallocations of portfolio funds based on stated risk and return goals. Ideally, this tool could

increase government financial efficiency by identifying and exploiting relationships between portfolio projects, thereby reducing financial risk while maintaining the overall portfolio expected return (or value).

E. SCOPE

Portfolio management can be conducted by various methods for groupings (portfolios) of: new projects, desired capabilities, life-cycle costs, and many others. In order to narrow the scope of this research, the only portfolio management method examined will be portfolio theory-based analysis. Additionally, only a small portfolio consisting of five representative Department of Defense acquisition programs with Earned Value data will be considered. As a practical matter, this means all programs considered in the portfolio analysis will be currently in procurement (i.e. in the Technology Development, System Development and Demonstration, or Production and Deployment acquisition phases) and valued over $73 million in Research, Development, Test and Evaluation (RDT&E) or over $315 million in procurement dollars (Fiscal Year 2000 constant dollars) (Department of Defense Directive 5000.2 [DoDD 5000.2], 2003).

F. METHODOLOGY

As a first step in judging the practicality of applying portfolio theory using EVM data, this research will draw selected EVM data from a representative and accessible government database. To demonstrate portfolio theory-based analysis while limiting the complexity and scope of this research, five representative programs from a typical acquisition portfolio will be selected for analysis. The raw EVM data extracted from the database will be presented and discussed. Potential methods of converting the EVM raw data into representative return on investment or “stock price” values will be examined, and a suitable conversion selected.

Based on this converted (normalized) EVM data, variances and co-variances between programs within the portfolio will be calculated. Potential "investor" (portfolio manager) goals for portfolio risk and return will be reviewed and a suitable strategy selected.

Two non-linear programming models with variables representing the potential weighting of each program, the calculated co-variance values, and selected "investment" (portfolio) constraints will be constructed and entered into selected software in order to determine "optimal" program weightings within the portfolio. The first model will be constrained primarily by the selected "investment" strategy (for instance maintaining return while reducing risk) and should yield an "optimal" portfolio. However, given that financial managers cannot and would not want to make the potentially dramatic weighting (funding) shifts required for an "optimal" portfolio, a second model with significantly more constraints will be analyzed. The second model will assume a reduction in portfolio value (funding) and will have constraints limiting the amount of weighting change programs can accept with a strategic goal of maintaining return while reducing risk.

G. LIMITATIONS

As previously discussed, this research will be limited to an analysis of five representative acquisition programs with EVM data. The analysis presented in this research cannot be directly applied to portfolios containing programs lacking EVM data. Analysis of larger EVM supported portfolios requires significantly more computation (exponential growth) and can easily exceed the capacity of un-tailored software packages. Relationships, if any, between the results obtained from this analysis and other portfolio management methods are not examined. This analysis gives only minor consideration (in the second model) to real-world requirements, political and social factors, or fiscal realities, which are likely to significantly impact funding allocation/reallocation decisions.

H. ORGANIZATION OF THESIS

This thesis is organized into five sections, an introduction, literature review, data collection and methodology, data analysis and results, and recommendations and conclusions. The introduction provides an overview of what this research is about, why it is important, its potential benefits, and how it will be conducted.

The literature review section familiarizes the reader with Modern Portfolio Theory (MPT), Project Portfolio Management, and EVM. The section also reviews existing research within these fields and common uses for each of the concepts. The section also presents and discusses various non-MPT based research employing "portfolio analysis" terms, in order that the reader may be familiar with alternative portfolio analysis definitions. Finally, the literature review presents three examples of research addressing non-traditional (non-financial) applications of MPT.

The data collection and methodology section presents and discusses the raw EVM data which form the basis of the ultimate analysis. A discussion of various conversion or data normalization schemes for the raw data is presented, and a favored method is selected. A discussion of the calculations required in computing the necessary co-variances is detailed. Two non-linear programming models are suggested and discussed with emphasis on the selection of a portfolio risk and return strategy and model constraints.

Data analysis and results are presented in the section of the same name. The quantitative portfolio weighting results are presented and their implications discussed for both models.

Finally, the potential application of the results to government portfolios is presented in the recommendations and conclusions section. Strengths and weaknesses of the analysis are discussed. Ideas for further research and integration of this research with other portfolio management techniques are also examined.

II. LITERATURE REVIEW

Although government and business differ in many ways, financial managers in both sectors are interested in determining where to invest resources to gain a desired return with a minimum of risk. Literature on this topic is extensive, generally falling into three categories: How to determine where to invest, how to monitor performance of current investments, and how to determine when to divest. Both government and business face challenges from top organizational levels to manage portfolios of projects or activities. Individually, each of the projects within a portfolio should support some or all of the organization's goals.

A review of the existing literature for applications of Financial Portfolio Analysis as contemplated by this research has yielded relatively few results. While the idea of applying portfolio theory to non-financial portfolios is not new, the lack of readily available market data upon which to perform the required statistical calculations make broader application problematic. Indeed, as Bonham (2005) relates, Markowitz himself acknowledged that others hoped to extend his theory to other portfolios, but he questioned the applicability due to differing constraints and other factors.

Accordingly, a review of the broader literature dealing with financial portfolio analysis as described by portfolio theory, the theory and practice of Project Portfolio Management (PPM), and the theory and application of EVM is presented to establish the foundational knowledge upon which this research builds. Then the small body of available literature dealing directly with financial portfolio analysis applications to non-financial portfolios is discussed.

A. MODERN PORTFOLIO THEORY (MPT)

Modern Portfolio Theory (MPT) stems from the work of Dr. Harry Markowitz (Reilly & Brown, 1997). MPT is the basis of today's portfolio theory. Markowitz (Markowitz, 1952) first describes the basis for MPT in an analysis of alternative portfolio selection strategies. In his seminal November 1952 *Journal of Finance* article, Markowitz examines two potential portfolio selection rules. The first rule has a financial portfolio manager select securities based on maximizing the portfolio's discounted expected return. This rule, or a variation, seems reasonable and was (and is) often used by investors. Using this rule the investor (or manager) picks only stocks with the highest expected returns in order that the sum of the individual stocks' expected returns will give the maximum aggregate, or mean, portfolio return.

Markowitz rejects the maximization of discounted expected returns rule because it gives no consideration to the accepted idea of portfolio diversification (Markowitz, 1952). The principle of diversification is generally recognized as valid and valuable. Diversification has been culturally enshrined in axioms like, "Don't put all your eggs in one basket," and is referred to in Shakespeare's *The Merchant of Venice* with a character stating he rests more easily knowing his fortunes are not dependent upon one ship, estate, or event (Rubenstein, 2002). Recent stock market examples can also be used to illustrate the risks of following a maximizing expected returns strategy. The rule had managers fill their portfolios with technology stocks during a period of rapid technology growth. While this strategy generated maximum returns for a period, it had significant investor risk when the trend reversed. Markowitz uses this rejection to remind the reader of the difference between investment and speculation- investment seeks the best return while accepting as little risk as possible, while speculation seeks the maximum return possible regardless of risk (Markowitz, 1952).

In contrast to the maximum return rule, Markowitz presents a second "expected returns – variance of returns (E-V) rule." This rule seeks to maximize expected returns for a given variance of returns (risk), or alternatively, to minimize variance (risk) for a given expected return. It is this rule that forms the

basis for Modern Portfolio Theory (MPT). Using statistical mathematics and analytical geometry, Markowitz demonstrates that this rule provides an efficient portfolio of stocks where expected returns are maintained while variance (risk) is minimized (Markowitz, 1952).

The unobvious truth Markowitz illuminates is that while expected returns are additive, the variances, or risks, are not- they depend upon the relationship (or correlation) between the individual stocks, known as co-variance. Thus, given two different portfolios with equivalent portfolio expected returns and variances (but with different individual components), an investor who invested equally in both portfolios, would enjoy the same expected return and a lower variance (risk) than if he or she invested everything in either of the two original portfolios. This seemingly paradoxical result stems from the fact that individual components within the two nominally identical portfolios can move in opposite directions, canceling out some of the variance in the aggregate portfolio. The Figure 1 plot of the calculated aggregate risk and return of the two-portfolio example assuming different co-variances illustrates the concept. If the two portfolios are perfectly correlated, the risk-return relationship for varying portfolio component weightings is linear connecting the two portfolios. As the correlation between the two portfolios decreases, the risk-return relationship becomes an arc between the two portfolios. When the two portfolios are perfectly negatively correlated, meaning as one portfolio goes up the other comes equally down, the arc is at its most distended. Markowitz more fully explores the mathematics and the resulting ramifications on sample financial portfolios and explores methods of evaluating portfolio components to develop an efficient portfolio (Markowitz, 1959).

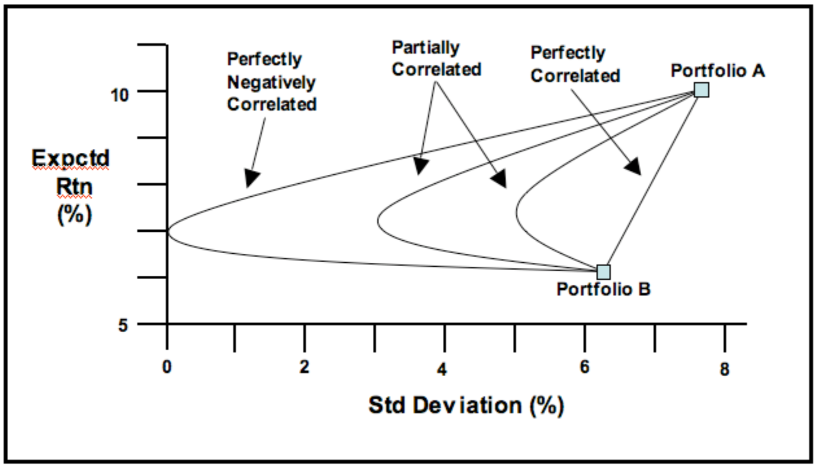

Figure 1. Portfolio Risk-Return Plots for Different Weights and Correlations (After Reilly & Brown, 2003).

Markowitz's rigorous portfolio selection theory is the basis for the financial portfolio analysis widely used today by financial managers. Markowitz' contribution to financial theory was recognized in 1990 when he was awarded the Nobel Prize in economics along with William F. Sharpe, and Merton H. Miller. Since MPT is based on sound mathematical derivation, the theory remains unchallenged and widely accepted. However, as with most theories, Markowitz makes several simplifying assumptions related to investor and market behavior.

The ultimate goal of MPT is to minimize the portfolio risk associated with a particular return, or, conversely, to maximize the return for a given level of risk. The desire to minimize risk or maximize return is based on certain rational assumptions about risk and return. For instance, investors are risk averse, avoiding any unnecessary risk in pursuing a return (Reilly et al., 2003). Second, investors require a higher return for bearing greater risk (Reilly et al., 2003). Finally, investors have a profit motive- they will select the investments with higher returns given the same level of risk (Reilly et al., 2003). MPT further assumes that financial markets are efficient, meaning that all relevant information about the firm underlying the security is known in the marketplace- that the stock's price is a fair representation of its value (Reilly et al., 2003). Additionally, Markowitz assumes that markets are liquid, meaning that the various assets are available and transactions occur quickly (Markowitz, 1952).

Ultimately, the inputs MPT uses are built on assumptions reflecting a simplified optimal reality, variations in the validity of any of which can result in sub-optimal portfolios. As Markowitz himself points out, “The Rational Man, like the unicorn, does not exist” (Markowitz, 1959). The various investor assumptions presented above break down in varying degrees in various situations. For instance, “PepsiCo may feel that it would be inappropriate to invest in Coca-Cola or Dr Pepper/Seven Up, Inc” despite its potential contribution to PepsiCo’s investment portfolio (Bonham, 2005). Recent trends in socially responsible investing and government regulations or requirements are additional examples where “rational” investor behavior may not be realized (Bonham, 2005). Despite these difficulties, portfolio managers continue to use MPT for portfolio management because it provides a valid, rational framework from which to start to make portfolio decisions. As alternative behavioral portfolio theories were proposed, some, such as Nevins, have responded by using the proposed behavioral theories to essentially modify the input data used by MPT (Nevins, 2004). Indeed, much of the difficulty in effectively employing MPT is in determining the expected return and variance (risk) values to be used in the portfolio analysis.

While Logue and Madura and Abernathy have documented difficulties in achieving the efficient portfolios outlined by Markowitz’s theory, it remains a primary tool and rational starting point for financial portfolio managers (Logue, 1982) (Madura & Abernathy, 1985). Two key difficulties faced by portfolio managers using MPT are: generating accurate expected return and variance values and how often to update, recalculate, and rebalance the portfolio. Because updating, recalculating, and rebalancing the portfolio takes time and incurs real world transaction costs, the costs of a sub-optimal portfolio must be weighed against the costs of the analysis and transactions required to make it once again efficient (Madura & Abernathy, 1985).

B. PROJECT PORTFOLIO MANAGEMENT (PPM)

Project Portfolio Management (PPM) is a relatively new management concept (Levine, 2005). Although the management of a portfolio of projects is applicable to a broad variety of industries, the Information Technology (IT) field has provided fertile ground for PPM due to the tremendous investment requirements and the spectacular failures it has produced. It is easy to envision how the rapid advances in IT hardware and software have enabled ever-expanding solutions to be offered to organizations. Often, these solutions are implemented as IT projects using current state-of-art technology. Unfortunately, as technology, organizational needs, and the number of projects increase, the cost, complexity, and digression from the originally envisioned benefits quickly grow (Levine, 2005). As a recent Government Accountability Office report notes, the sheer size of IT spending in the federal government - 64 billion dollars in the President's 2007 Budget (Powner, 2006); and testimony before Congress indicates a desire to ensure that these funds are not squandered on risky and or redundant projects (Evans, 2004); have further accelerated IT PPM efforts.

Fundamentally, PPM seeks to select and guide projects which give the organization the best-expected return for a given level of risk. As such, PPM is conceptually tied to Markowitz's MPT. Indeed, PPM has its origins in MPT, in that the goals of project portfolio managers are largely the same as those of Markowitz's financial portfolio managers; namely, to "maximize return for a given risk," "minimize risk for a given return," "avoid high correlation," and "[tailor] to the individual company" (Bonham, 2005). However, "the additional complexities project management brings to MPT" have made it difficult to quantify into data suitable for the quadratic programming methods used for financial portfolio analysis (Bonham, 2005). Thus, PPM attempts to achieve the goals of MPT by using management processes to evaluate and monitor project portfolios.

A key tenet of PPM discussed in literature is the requirement for "strategic alignment" (Bonham, 2005) (Levine, 2005). The PPM strategic alignment process checks to ensure that a project supports the overall organization's goals. While this may seem obvious, large organizations with various internal divisions or units

have embarked upon projects that met the needs of the internal unit while failing to support the goals of the overall organization. Ultimately, PPM strategic alignment is an attempt to value a project's "expected return."

Consider two projects for a package delivery company with the same estimated costs, risks, and estimated savings; one project tracks packages more efficiently, the other tracks company health-related expenses. Both are beneficial, however the package tracking project is more aligned with the strategy of the company. In valuing the two projects the package tracking project should have a greater expected return compared to the health-related expense tracker. An appropriate output of a PPM strategic alignment process would be a prioritized value ranking of potential projects (Bonham, 2005) (Levine, 2005).

PPM evaluates risk between projects by primarily qualitative or analogous measures. Bonham believes that project process "flexibility" should be considered to reduce risk (Bonham, 2005). At its heart, PPM attempts to reduce risk by ensuring that some level of management is evaluating potential projects, providing resources for approved projects, monitoring project interrelations and interactions, and redirecting or terminating projects that no longer support the organization's strategy.

C. EARNED VALUE MANAGEMENT (EVM)

EVM as a management tool for project managers has been in use for approximately forty years (Westcott, 2006). The primary driving force behind the implementation of EVM in the United States has been federal law, which has required the use of EVM on projects or programs exceeding certain financial thresholds ("OMB Ratchets," 2005). In addition to government projects, EVM has attracted support from various private-sector industries and academic institutions involved in financial and accounting research.

EVM measures a single project or program's performance against a defined project or program plan (Ruskin, 2004). In order for EVM to be successfully employed, all the tasks that collectively make up the project must be reasonably identified before the project begins. The individual tasks are

commonly mapped out in a traditional Work-Breakdown Structure (WBS) and Work Package graphics identifying estimated cost, duration, and any task interdependencies (Ruskin, 2004). This naturally leads to speculation that EVM may be unsuitable for projects where evolving requirements and technologies are present. However, the federal government has successfully used EVM for cost-reimbursable contract management, a contract type specifically chosen when a project or program is expected to evolve. Additionally, reasonable evidence has been presented that EVM can be adapted to programs using "spiral development," a development methodology meant to deal with uncertain and changing requirements and technologies (Brownsword and Smith, 2005).

As an illustration, a project requiring construction of a simple, wooden chair could be defined with the following four tasks: purchase wood, cut wood to plan, assemble chair, paint chair. The first task might have the following duration, cost, and interdependencies: four hours to select, purchase, and transport wood; a total cost of 60 dollars (40 dollars of labor at 10 dollars an hour, 18 dollars in materials, and 2 dollars for transportation); and a task interdependency requiring that this task be accomplished before any other task. In similar fashion, the cutting task is estimated to take two hours, 22 dollars, and must occur after purchase and before assembly. Assembly will take half an hour, cost 15 dollars, and must occur after purchase and cutting. Painting will take one hour, cost 20 dollars, and must be done after purchase and cutting, but either before or after assembly. A Gantt Chart depicting the Work Packages for the chair example is shown in Figure 2.

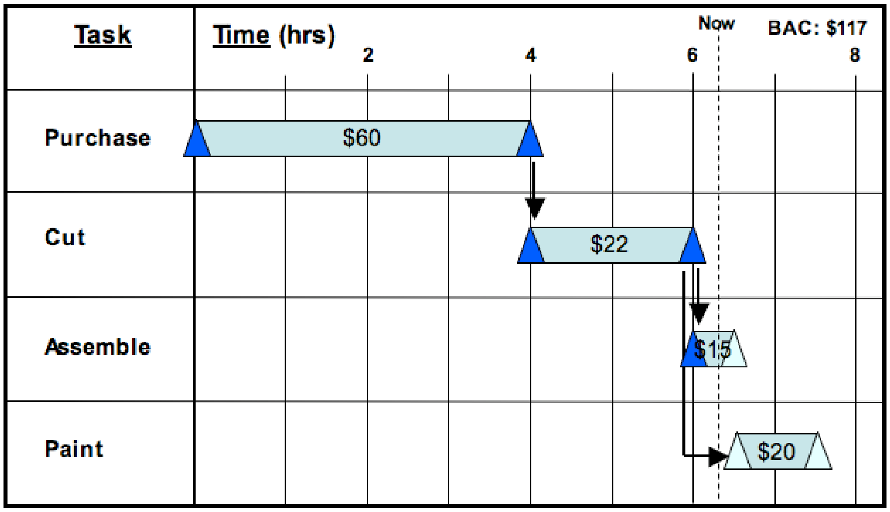

Figure 2. Work Package, Chair Construction Project.

EVM captures three primary measures: planned work, actual work completed, and scheduled work completed (Ruskin, 2004). For government contracts, this information is transmitted in Cost Performance Reports (CPRs) and Contractor Cost Data Reports (CCDRs). The differences, referred to as "variances," between these three measures give the project manager an indication of whether the project is proceeding on budget and schedule. It is important to note that the "variances" discussed in EVM are not the same as the mathematical variances of statistics, but are simply the difference between planned and actual values. From these basic measures various additional ratios and estimates related to the project can be made. Although the Work Packages contain additional information, the dollar values of the tasks are the salient measure by which management evaluates the progress of the project. From the example above, the wooden chair project tasks can be totaled, indicating that overall the project is expected to take 7.5 hours and cost 117 dollars. The 117 dollar cost at project completion is referred to as the Budget At Completion (BAC).

Some of the differences in the practical application of EVM occur in how work is credited toward a project once underway. Although there are many permutations, three basic methods stand out: the fifty percent rule, the percentage complete rule, and the work phase rule. Using the fifty percent rule,

a task is considered fifty percent complete once work on the task is started. The remaining fifty percent is credited to the task when the task is completed. Tasks are marked as started by filling in the leading task triangle and marked as completed by filling in the trailing task triangle. The percent complete rule uses professional judgment or some other metric to determine what percentage of the task is completed. Finally, the work phase rule assigns percentages to various phases of the task and uses the summed percentages of the phases underway and previously completed to determine the percent of the task complete (Ruskin, 2004). Thus, a task may have a design, a build, and a test phase with thirty percent, thirty percent, and forty percent respective phase weightings.

Assuming the wooden chair project has commenced, various EVM calculations can be performed (the fifty percent rule is used). Information available to management is that the project started 6.3 hours ago (marked in Figure 2 as "now"), that the purchasing and cutting tasks have been completed, the assembly task has begun, and that 92 dollars have been spent. The 92 dollars is the Actual Cost of Work Performed (ACWP) in that this is the amount of costs incurred to date. Next, management examines the Work Package to determine the amount of work expected to be performed in the first six hours. According to the plan, purchasing at 60 dollars and cutting at 22 dollars, for a total of 82 dollars, was expected- this is the Budgeted Cost of Work Scheduled (BCWS). Finally, the tasks actually completed or underway are examined. Purchasing and cutting have been completed, representing 82 dollars of work, and assembly is underway, meaning that the task is 50 percent complete, or 7.5 dollars complete. Summing these values results in 89.5 dollars of Budgeted Cost of Work Performed (BCWP).

Management can now determine schedule variance by subtracting the plan from the actual, or BCWP minus BCWS (89.5 dollars minus 82 dollars), to be 7.5 dollars ahead of schedule (a positive result). Similarly, management can compare budgeted costs with actual costs to determine budget "variance" by subtracting ACWP from BCWP (89.5 dollars minus 92 dollars) resulting in a negative 2.5 dollars (over cost). Thus, EVM shows the wooden chair project to

be ahead of schedule (by 7.5 dollars) and over budget (by 2.5 dollars). Management typically conducts a variance analysis to determine causes and potential solutions. In this case, further investigation may find that a highly-skilled worker was used to construct the chair. The highly skilled worker completed the task more quickly than planned and was paid a higher labor rate than planned. Management can also determine whether this was a one-time (regular worker out sick) or recurring event (highly-skilled worker only employee), and take action to correct the situation.

The variance information can also be used to produce an updated estimate for the cost of the entire project, referred to as the Estimate At Completion (EAC). EAC can be calculated using different methods, depending on the nature of the variances (Defense Acquisition University [DAU], 2005). One method has EAC equalling the value of the actual work completed to this point, plus the remaining work scheduled divided by an efficiency factor (called the Cost Performance Index [CPI]), which corrects the remaining work for how well the project has been performing. 92 dollars has been actually spent, which is added to the work remaining (BAC – BCWP, 117 dollars minus 89.5 dollars) 27.5 dollars divided by the efficiency factor CPI (BCWP/ACWP, 89.5 dollars divided by 92 dollars) 0.973, or 28.26 dollars, yielding an EAC of 120.26 dollars. Thus the overall project variance (or Variance At Completion [VAC]) at this point is BAC minus EAC- 117 dollars minus 120.26 dollars, or 3.26 dollars.

"EVM is a standard tool of commercial and government managers for the evaluation of various types of projects," and is, "…such a useful tool that it has been approved as an American National Institute Standard, ANSI 748" (Alvarado, Silverman &Wilson, 2004). EVM, "…is considered the best method for tracking and controlling the performance of a project. Earned Value provides leading indicators of future problems as well as the magnitude and significance of performance issues in current and past periods" (Westcott, 2006). Research examining several 1990s defense programs to determine whether EVM produced reliable predictive information on program budget and schedule trends has been done (Christensen & Templin, 2002). The research found that EVM did fairly

accurately bound final program costs from early program development (Christensen & Templin, 2002). However, despite a forty-year history and general success, EVM is still used on only approximately one percent of projects (Marshall, 2005). Marshall surmises that the federal government's requirement that mainly large cost-reimbursable (CR) projects utilize EVM appears to have created a bias in the private-sector to adopt EVM only for a relatively small number of large CR projects.

D. APPLICATIONS OF MPT TO NON-TRADITIONAL PORTFOLIOS

The literature pertaining to applications of MPT portfolio analysis of non-traditional (i.e. non-financial) portfolios is fairly limited. The reason for this limited body of literature appears to be the difficulty in identifying suitable project data upon which to apply MPT. Three common data issues plague non-financial portfolios. First is the lack of quantifiable data, especially during initial project selection. Most data are qualitative at this stage, and any available quantitative data tend to be subjective and highly dependent upon the data source. This is distinctly different from financial stock portfolios, where the evaluation of a particular stock not yet in the portfolio can be accomplished using daily closing prices for the stock in question. For non-financial portfolios, such as an Information Technology portfolio, an established market value, or price, for emergent technology is not available and various estimates or approximations must be used.

The second difficulty is that even where data are available, they are often not uniform across the various projects in the portfolio making the results of a MPT analysis suspect. For a financial portfolio the stock price and its variation over time represent the market's judgment of the value and risk of the underlying enterprise regardless of the industry. Thus, a car manufacturer and a computer chip-maker are judged by the same standard, stock price and variation, rather than by top speed, number of cars sold, chip throughput, and memory capacity. By contrast, an Information Technology portfolio might have a fielded technology project judged by an observed Return on Investment (ROI), an upgrade project

by an existing technology judged on an extrapolation of the current version's Net Present Value (NPV), and an emerging technology project by using a marketing gross sales revenue estimate. Comparing these projects requires conversion (or normalization) of data that are disparate and of differing quality.

The third difficulty stems from the varying data "timelines" of non-financial portfolio projects. In financial MPT analysis, data timing is set by the market and is reducible to daily closing price. In contrast, an Information Technology portfolio often contains projects with differing data reporting periods. Some projects may be fielded and generating monthly revenue data, others may be in development with quarterly cost data, and still others may rely on the estimates generated during the project approval phase until fielding. These differing data timelines make it difficult to conduct a meaningful comparative MPT analysis.

Given these data difficulties, the literature dealing with non-financial portfolio analysis tends to fall into two broad categories- reports and studies which detail unique, non-MPT, portfolio analysis techniques, and those which attempt to apply MPT analysis to non-financial market data.

1. Non-MPT Based Portfolio Analysis Research

While the literature dealing with unique, non-MPT portfolio analysis techniques is not directly applicable to the work contemplated in this research, it is important to acknowledge this literature because of the confusion it can generate for those new to MPT due to the use of "portfolio analysis" terminology.

Several instances of the use of portfolio analysis nomenclature are found in the literature. The Office of Management and Budget requires portfolio analysis of Information Technology (IT) projects in its A-11 Circular (Office of Budget and Management [OMB], 2006). Specifically, OMB budget submission guidance requires that, "…portfolio analysis to determine continued viability…" be conducted (OMB, 2006). As mentioned before, this requirement appears to have been driven by two imperatives, first, the sheer size of the federal IT spending- 64 billion dollars in the President's 2007 Budget; and second, a desire to ensure

that these funds are not squandered on risky and/or redundant projects. However, OMB does not define how to conduct portfolio analysis, leaving government agencies to determine how to accomplish it.

As a result of the government portfolio analysis requirement, numerous commercial vendors began offering software based portfolio management and analysis tools to government agencies. Representative vendor literature promises, "… continuous portfolio and project assessment including measurements of actual versus projected performance, earned value reporting, and comprehensive spending summary analysis" (www.niku.com, 2004). While these offerings are helpful in capturing and organizing project data, they ultimately present statistical data for management's use in conducting its own portfolio analysis as opposed to a quantitative calculation of an MPT efficient portfolio.

The research and development (R&D) field has also generated literature on portfolio analysis. Government organizations and universities involved in R&D have developed portfolio management and analysis methods to attempt to optimize the risk-return ratio of their projects. An example of such a method is an automated R&D portfolio management decision framework for the Office of Naval Research, which was developed to support portfolio decision-making (Silberglitt, 2004). The decision aid took various specific R&D project attributes as inputs and combined and plotted them on a risk-return type graph. The model performs statistical calculations, using specific qualitative and quantitative data collected for the various projects. As opposed to MPT analysis which generates a quantitatively efficient solution, this model and many similar R&D portfolio management techniques essentially perform PPM data collection and presentation, then define decision bodies and processes which conduct qualitative "portfolio analysis."

Another example of a federal government implementation of portfolio management and analysis is the Missile Defense Agency's automated portfolio solution tool (Dreyer & Davis, 2005). The model accepts inputs of various missile defense requirements and scenarios and formats these data into a series of

charts depicting the trade-offs calculated based upon the inputs given (Dreyer et al., 2005). Despite its "Portfolio-Analysis Tool for Missile Defense" name, the implementation is more of a capabilities simulation rather than a portfolio analysis tool. While various risk and return related variables are inserted into the model, and several charts and graphs depicting the likely outcomes are presented, the model provides the user with results that the user then manually compares. Indeed, the tool's developers state as much when they say, "Its purpose is to help frame, manipulate, and present multi-faceted information to decision-makers, particularly with capabilities-based planning in mind" (Dreyer et al., 2005).

2. MPT-based Portfolio Analysis Research

In contrast to the unique "portfolio analysis" application literature described above, the literature detailing efforts to apply MPT analysis to non-financial market data is directly applicable to this research. As mentioned, the volume of literature is relatively sparse due to the data difficulties previously noted; however, three representative studies discussed below provide a representative foundation.

A study of Federal Aviation Administration (FAA) plans to improve the safety, capacity, and reliability of the National Airspace Structure (NAS) provides a lucid argument for applying MPT to a federal government portfolio of projects- in this case NAS improvement projects (Bhadra & Morser, 2006). As Bhadra and Morser outline, the FAA has been embarked upon a phased plan to improve the safety, capacity, and reliability of the National Airspace (NAS) for the past decade. Additional security issues, which arose after the September 11th, 2001 aircraft hijackings, have modified FAA plans and provided a sense of urgency. While the FAA has plans in place, it does not have an established method to analyze its system wide investments. Bhadra and Morser propose Portfolio Management and Analysis as a viable means to accomplish this analysis (Bhadra et al., 2006). With 40,000 scheduled commercial departures and 1.5

million passengers daily, 315 air traffic control centers, and a $14 billion annual budget, a MPT efficient portfolio that maximizes return for a given level of risk could have a significant impact (Bhadra et al., 2006).

In discussing the portfolio approach, Bhadra and Morser make some observations that attempt to identify and deal with the challenges of using a financial portfolio analysis methodology in a government setting. Specifically, they observe that, “FAA investment selection criteria, as with most government investment, require special consideration due to the lack of market signals. In the business world, good investments differentiate themselves from bad investments through measures of return. … FAA investment occurs outside of a market and focuses on air traffic management, safety, and efficiency. There are no alternative air traffic service providers with a different portfolio of investments from which consumers can buy air traffic services thus providing market value signals” (Bhadra et al., 2006).

The insights presented in Bhadra and Morser’s study were recognized as valuable by the *Journal of Air Transportation* which awarded the study their annual “Sorenson Best Paper Award.” However, while Bhadra and Morser provide an excellent review of financial portfolio theory and analysis and postulate that portfolio management would provide the FAA with a better risk return ratio than current methods in use, they ultimately never provide an example using data available to the FAA in support of their argument. Thus, the thorny problem of how to measure returns and risks and consistently apply them within the financial portfolio model is sidestepped and ultimately recommended by Bhadra and Morser as a topic for further study.

Within the private-sector, real estate investment firms have devoted considerable energy in attempting to apply MPT to real estate portfolios. An active debate within real estate portfolio manager circles on the usefulness and applicability of MPT has been underway (Reinbach, 1993). Reinbach records the discussions between the founder of MPT Dr. Harry Markowitz and real estate portfolio managers, “who together represent[ed] some three-quarters of the $120 billion institutional real estate portfolio” (Reinbach, 1993). Given the significant

dollar value of real estate portfolios, many real estate investment groups are looking for a rational means to maintain returns while reducing overall risk. As Reinbach records, a significant number of real estate portfolio managers are attempting to use MPT to produce efficient portfolios. However, other portfolio managers dispute the applicability of MPT to real estate stating that the markets are fundamentally different.

In discussion, Markowitz indicated that he believes MPT can be successfully applied to real estate portfolios, but that significant hurdles exist, "the most challenging part of the problem…is the lack of reliable data" (Reinbach, 1993). To help resolve the lack of reliable data, Markowitz provided two suggestions, first that, "the real estate data should include both survivors and casualties of the past several real estate cycles," and that, "the proprietary data which the group had individual access to at their companies were pooled in a way that would allow the intellectual market to exert its invisible hand" (Reinbach, 1993). Both of these suggestions address data reliability. Keeping data on real estate investment casualties as well as survivors is important to accurately capture the actual variance, or risk of the investment types. The portfolio which keeps profitable retail properties in their portfolio while selling the unprofitable ones, usually only has data on the successful survivors, making accurate assessment of retail property variance, or risk, biased. Similarly, firm-specific data on portfolios are not generally available to outsiders limiting the broader market's ability to arrive at a representative, uniformly applied valuation for properties. Markowitz also presents two additional issues which hamper the successful application of MPT to real estate portfolios- the lack of a quantifiable real estate pricing theory to account for the illiquidity of the real estate market, and the large investor effect which states that large investors find it difficult to beat the market since they are essentially "the market" (Reinbach, 1993).

A summary of previous studies of MPT real estate portfolios found that portfolios constructed using historical real estate data performed poorly in subsequent periods (Lee and Stevenson, 2005). One researcher has attributed this poor performance to the inter-temporal instability of the portfolio weights,

meaning that the percentage of different property types within the portfolio change significantly with time (Lee, 1998). Other research has found that the longer a real estate portfolio was held from the time the data upon which it was selected was collected, the worse the portfolio performed (Jorion, 1985). Lee and Stevenson cite additional studies which found that the mean return of real estate investments varied considerably over time and were not generally predictable from “ex ante” historical performance data, while their variances and covariances remained relatively stable and therefore more accurately predictable (Lee et al., 2005).

Based upon these findings, Lee and Stevenson studied whether various measures of estimation risk used in financial portfolio analysis might improve future portfolio performance. Lee and Stevenson found that while these techniques helped, they were not completely successful in resolving poor future performance (Lee et al., 2005). Overall it appears that the cyclical nature of real estate markets needs to be captured in order to predict future return performance when constructing real estate portfolios.

A final application of MPT within the private-sector is provided in a study of private investment in wind farms (Dunlop, 2004). Dunlop presents the case for using MPT to develop energy production efficient wind farm portfolios. Dunlop points out that one of the difficulties encountered by wind farm owners is the variation in energy production of a particular farm due to fluctuations in the amount of wind over time. For instance, Dunlop points out that, “Germany had a very bad wind year in 2001, with the wind blowing 30% less than historical averages…[i]n contrast, Italy had a great wind year in 2001, with reported yields much higher than average” (Dunlop, 2004). Given that wind farm profitability is in large part driven by the amount of power generated, “[I]nstead of owning one large 100 megawatt (MW) wind farm in the U.K., we might be better off owning a 50 MW wind farm in the U.K. and a 50 MW wind farm in Spain. This is because when the wind is not blowing in Spain, it might be blowing in the U.K., and vice versa” (Dunlop, 2004).

Dunlop goes on to calculate the risk and return (production) of several wind farms located in the European Union (EU) and the United States, determining the "beta," or the ratio of individual farm risk to the overall portfolio risk. Dunlop demonstrates that higher returns can be realized by wind farm investors at the same level of risk by diversifying their wind farm holdings. Furthermore, Dunlop argues that a significant difference between wind and stocks is that future wind value can be much more accurately forecast than future stock prices. It allows MPT to shine in wind farm portfolio analysis because the input data is much more predictive than stock input data. Dunlop was able, "…to diversify away 30% of total risk with [his] Southern EU and U.S. Portfolio. Moreover, [his] Southern EU and U.S. Portfolio carried only one-third the risk of a single typical Northern European wind farm" (Dunlop, 2004).

E. SUMMARY

Having reviewed the literature and theory underpinning MPT, PPM, and EVM and presenting various non-financial MPT applications, this research will propose a potential combinatorial application of MPT and EVM to produce meaningful project portfolio insights for government financial managers.

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III. DATA COLLECTION AND METHODOLOGY

To illustrate the financial portfolio concepts discussed in the literature review and demonstrate their application, a portfolio of five representative stocks was collected and analyzed. Each step in the process is discussed and the requisite calculations presented.

With the understanding gained from examining the application of financial portfolio analysis within a traditional stock portfolio setting, a representative government portfolio was selected, the available EVM data presented, and analysis methodology discussed.

A. SAMPLE ANALYSIS OF A STOCK PORTFOLIO

1. Selection of Representative Stocks

For a stock portfolio, the "common" attribute is that all items in the portfolio be stocks. For this example analysis the selected stocks will be listed on the New York Stock Exchange (NYSE). Further, for the purposes of this example, the number of companies with stocks within the portfolio will be limited to five. This limitation will serve to illustrate the geometric growth in the number of calculations required of larger portfolios, while limiting the amount of information the reader must process and digest. This limitation also ensures that the example mirrors the scope restriction placed on the government portfolio to be subsequently examined. Finally, since the example is meant to be analogous with the eventual government portfolio, and many government portfolios contain similar types of programs, the example stock portfolio was selected from within an industry. In other words, since a likely government portfolio might group "counter-mine warfare programs" together, it is reasonable to limit the example stock portfolio to a similarly constrained field or industry.

In accordance with the limitations discussed above, a stock portfolio from the oil sector has been arbitrarily selected. Two major integrated oil and gas

companies, Exxon Mobil and Chevron, with respective stock symbols XOM and CVX are included. Two oil and gas refining and marketing companies, Royal Dutch Shell (RDS-B) and Valero (VLO), and one oil and gas equipment and services company, Baker Hughes International (BHI) round out the portfolio. Again, while the selection of the industry and companies is arbitrary, the reasoning behind the selections follows the logic outlined above.

2. Required Data

Having selected a portfolio of five oil industry stocks, data on the performance of these stocks is required. Specifically, the closing price of the various stocks at regular intervals over a set period of time is needed. As in many other areas, the internet provides a ready source for these data. A search provides a wealth of websites containing stock price information.

The internet source selected must meet data consistency, accessibility, availability requirements. Specifically, the site must consistently collect the same data for all stocks so that the subsequent calculations capture performance variations and not data collection variations. The site must be generally accessible for verification and duplication purposes. Finally, the site must be available for future use, since the requisite data for analysis need to be periodically updated. Based upon these criteria, this research elected to use data collected from the Yahoo Finance website (Yahoo Finance, 2007).

For convenience, the period and frequency of the stock price data will be selected to match the frequency and period of the government EVM data to be subsequently analyzed. In general, EVM data are reported monthly via Cost Performance Reports (CPRs). Depending on the end-user, CPR EVM data may be further consolidated into quarterly reports for high-level review. From an analysis standpoint, the greater the data frequency, the more data points are available and the less likely any single data point will have a significant statistical impact. From a practical data collection standpoint, the greater the frequency of the data, the more challenging it becomes to collect and collate. Although many

sources of EVM exist, this research will draw EVM data from existing government databases. For reasons discussed subsequently in the EVM Data Source section, quarterly stock data will be used.

The selection of the period of collection presents more of a challenge, since government EVM data are collected for the duration of the acquisition project, with projects starting at different times and having different durations. This research will use the last three years of data as the period. While this period selection is, ultimately, arbitrary, the following reasoning was used in arriving at the three-year period.

A three-year period ensures that only recent performance variations are captured while ensuring that adequate observations are available (three years of quarterly data yield twelve observations). When making current portfolio allocation decisions, recent performance is arguably the most relevant. During the “dot.com” bust, the fact that a portfolio had a ten-year average return of fifteen percent, was less meaningful to a current investor than the fact that the portfolio’s three-year average return was negative ten percent.

3. Data Elements

The requisite stock data were collected from the Yahoo Finance website (Yahoo Finance, 2007). Date ranges representing the most recent three years were entered and “monthly” was selected from the menu provided. For each of the five oil sector stocks, data representing the monthly date, opening price, high price, low price, closing price, dividends, and an adjusted closing price were presented. The data were downloaded as a comma delimited text file using the “download” link provided. The text file was then imported into Microsoft Excel.™

Since only quarterly date and adjusted close price data are required, the extra rows and columns are deleted, leaving thirteen entries and twelve quarterly periods of data. The “adjusted closing” price is a “normalized” closing price that accounts for any dividends or stock splits during previous periods, thus ensuring that all returns are reflected in a single, adjusted price (Yahoo Finance, 2007).

The first two columns of Table 1 contain the data elements described for Exxon Mobil. The remaining stocks' data were tabulated in the same manner, but the tables are omitted for brevity.

4. Calculation of Stock Statistical Measures

From the quarterly adjusted stock price data, several statistical measures are calculated for use in subsequent portfolio analysis.

The performance of the stock over time is calculated by computing the stock's return for each quarter. The return reflects the rate of change of the stock's price and is indicative of the trend in stock price. Quarterly return is calculated by: taking a quarter's adjusted closing price, subtracting the previous quarter's adjusted closing price, and then dividing the difference by the previous quarter's adjusted closing price. The quarterly return is found in the third column of Table 1.

An average, or "expected," quarterly rate of return (denoted by E(R)) is then calculated by: adding the twelve quarterly returns and dividing the sum by twelve. Average quarterly return is shown at the bottom of the third column in Table 1.

In the fourth column of Table 1, the deviations in quarterly returns are calculated by subtracting the "expected" return (the average) from the actual calculated quarterly return (denoted by R – E(R)). Because the deviation is calculated from the "expected" return, the sum of the twelve quarterly deviations will be zero. In order to compute an "average deviation," the deviations in the fourth column are squared and the result entered in the fifth column (denoted by R – E(R)^2). At the bottom of the column, the squared deviations are summed and divided by the twelve observations to compute an average deviation, otherwise known as the variance. Below this value at the bottom of the fifth column, the square root of the variance, or standard deviation, is computed.

Exxon-Mobil (XOM) 03-01-04 03-01-07 [Mjr Intgd Oil & Gas]				
Date	**Adj Close***	**Qtrly Rtn**	**R - E(R)**	**(R - E(R))^2**
3/1/04	39.12	-		
6/1/04	42.04	0.0746	0.0204	0.00041437
9/1/04	46.03	0.0949	0.0406	0.00165027
12/1/04	49.08	0.0663	0.0120	0.00014340
3/1/05	57.34	0.1683	0.1140	0.01299842
6/1/05	55.58	-0.0307	-0.0850	0.00722163
9/1/05	61.75	0.1110	0.0567	0.00321774
12/1/05	54.86	-0.1116	-0.1659	0.02751119
3/1/06	59.76	0.0893	0.0350	0.00122726
6/1/06	60.55	0.0132	-0.0411	0.00168646
9/1/06	66.53	0.0988	0.0445	0.00197805
12/1/06	76.31	0.1470	0.0927	0.00859613
3/1/07	70.99	-0.0697	-0.1240	0.01537642
	Ave Qtr Rtn:	***0.0543***	**Sum:**	0.08202134
			Variance:	0.00683511
***(Yahoo,2007)**	**Weight:**	0.2000	**Std Dev:**	***0.0826747***

Table 1. Data Elements and Performance Calculations for Exxon Mobil

5. Calculation of Portfolio Statistical Measures

With the individual stock's statistical attributes calculated, the relationships between the various stocks can be calculated. The relationship between the deviations of two stocks, called the co-variance, is calculated by multiplying the quarterly deviations of each stock together. Co-variances are computed for each pair of stocks for each quarter and are presented in columns two through six in Table 2. The quarterly stock pair co-variances are summed and appear at the bottom of each column. This sum is then divided by the number of observations (twelve) to calculate the stock pair's co-variance over the period, displayed at the bottom of each column in Table 2. A summary of the calculated values for all five oil sector stocks is provided in Table 3.

Exxon-Mobil (XOM) 03-01-04 03-01-07 [Mjr Intgd Oil & Gas]					
	Covariance Calculations				
Date	**XOM-XOM**	**XOM-BHI**	**XOM-CVX**	**XOM-RDS-B**	**XOM-VLO**
6/1/04	0.00041437	-0.00046808	0.00065681	0.00161835	0.00189873
9/1/04	0.00165027	0.00432032	0.00409444	-0.00117108	-0.00203290
12/1/04	0.00014340	-0.00095407	-0.00074589	0.00136901	-0.00007015
3/1/05	0.01299842	-0.00146390	0.00794642	0.00468736	0.05427690
6/1/05	0.00722163	-0.00805458	0.00689209	-0.00323160	0.00496920
9/1/05	0.00321774	0.00628088	0.00666963	-0.00052133	0.01650320
12/1/05	0.02751119	0.00622303	0.02728772	0.01582083	0.03752449
3/1/06	0.00122726	0.00242713	-0.00067546	-0.00078131	0.00070062
6/1/06	0.00168646	-0.00575972	-0.00128572	-0.00170322	0.00105857
9/1/06	0.00197805	-0.00994668	0.00020620	-0.00237399	-0.01624059
12/1/06	0.00859613	0.00358475	0.00866587	0.00084904	-0.01338663
3/1/07	0.01537642	0.02274035	0.01519735	0.01419998	0.00053888
Covar Sum:	0.08202134	0.01892942	0.07490947	0.02876204	0.08574032
Covar Ave:	***0.00683511***	***0.00157745***	***0.00624246***	***0.00239684***	***0.00714503***
Correl Coeff:	1.00000000	0.17030886	0.85984304	0.44556078	0.41030268

Table 2. Paired Co-variance Calculations for Exxon Mobil.

			Covariance Matrix				
	E(R)	S.D.	XOM	BHI	CVX	RDS-B	VLO
XOM	0.0543	0.0827	0.0068	0.0016	0.0062	0.0024	0.0071
BHI	0.0582	0.1120	0.0016	0.0126	0.0045	0.0024	0.0081
CVX	0.0486	0.0878	0.0062	0.0045	0.0077	0.0019	0.0077
RDS-B	0.0404	0.0651	0.0024	0.0024	0.0019	0.0042	0.0051
VLO	0.1399	0.2106	0.0071	0.0081	0.0077	0.0051	0.0444

Table 3. Summary of Individual and Paired Stock Calculations.

The correlation coefficient for each stock pair is calculated and displayed at the bottom of Table 2. The correlation coefficient is the ratio of the computed co-variance between one stock and another, and the variance of the stock by itself (variance is the square of the standard deviation). The correlation coefficient is provided for mathematical cross-check and informational purposes. A correlation coefficient of one means the paired stocks move in perfect synchronization (pairings of a stock to itself should be perfectly correlated), a negative one indicates that the stocks move in perfectly opposite directions, and

zero indicates no relationship between the pairings. The correlation coefficient provides an easy way to quickly determine the nature of the relationship between two stocks.

With the above calculations available, the performance attributes for the portfolio can be calculated. The quarterly rate of return for the portfolio is simply the sum of the products of individual stock's expected return (E(R)) multiplied by its weight (W_x) within the portfolio (Markowitz, 1959). In the case of the oil stock portfolio, the dollar weightings for each of the stocks within the portfolio as defined as follows:

W_1 = portfolio weighting of Exxon Mobil (XOM)
W_2 = portfolio weighting of Baker Hughes International (BHI)
W_3 = portfolio weighting of Chevron (CVX)
W_4 = portfolio weighting of Royal Dutch Shell (RDS-B)
W_5 = portfolio weighting of Valero (VLO)

As an example, if the portfolio contained equal dollar amounts of all five stocks (each stock 20% of portfolio), then the portfolio's quarterly expected return (using E(R)s from Table 3) would be:

$$\begin{aligned} E(R)_{Port} &= W_1E(R)_1 + W_2E(R)_2 + W_3E(R)_3 + W_4E(R)_4 + W_5E(R)_5. \\ &= .2(0.0543) + .2(0.0582) + .2(0.0486) + .2(.0404) + .2(0.1399) \\ &= 0.06282 \text{ or } \underline{6.282\%} \end{aligned}$$

The next step is to calculate the portfolio's standard deviation. As discussed in the literature review section, Markowitz's insight was that the standard deviation of a portfolio is not simply the weighted sum of the individual stock standard deviations, but rather depends upon the relationships (co-variances) between the various stocks within the portfolio (Rubinstein, 2002). The co-variance is simply the correlation coefficient of a pair of stocks times the standard deviations of the two stocks. The five stock example portfolio's standard deviation is calculated by adding each stock's squared weight times its

squared standard deviation and then adding twice the co-variance of each stock pair divided by the product of the standard deviation of each stock in the pair, and then taking the overall sum's square root (Markowitz, 1959). Using the values found in Table 3, the quarterly standard deviation of the example portfolio (assuming equal stock weightings) would be:

$$
\begin{aligned}
\sigma_{Port} &= (W_1^2\sigma_1^2 + W_2 2^2\sigma_2^2 + W_3^2\sigma_3^2 + W_4^2\sigma_4^2 + W_5^2\sigma_5^2 + 2(W_1W_2cov_{12}) \\
&\quad + 2(W_1W_3cov_{13}) + 2(W_1W_4cov_{14}) + 2(W_1W_5cov_{15}) + 2(W_2W_3cov_{23}) \\
&\quad + 2(W_2W_4cov_{24}) + 2(W_2W_5cov_{25}) + 2(W_3W_4cov_{34}) + 2(W_3W_5cov_{35}) \\
&\quad + 2(W_4W_5cov_{45}))^{0.5} \\
&= .(2^2(0.0827)^2 + .2^2(0.1120)^2 + .\ 2^2(0.0878)^2 + .\ 2^2(0.0651)^2 + \\
&\quad + .\ 2^2(0.2106)^2 + (2(.2)(.2)(0.0016)) + (2(.2)(.2)(0.0062)) \\
&\quad + (2(.2)(.2)(0.0024)) + (2(.2)(.2)(0.0071)) + (2(.2)(.2)(0.0045)) \\
&\quad + (2(.2)(.2)(0.0024)) + (2(.2)(.2)(0.0081)) + (2(.2)(.2)(0.0019)) \\
&\quad + (2(.2)(.2)(0.0019)) + (2(.2)(.2)(0.0077)) + (2(.2)(.2)(0.0051)))^{0.5} \\
&= 0.08241 \text{ or } \underline{8.24\%}
\end{aligned}
$$

Putting these calculations into dollar terms, an equally weighted five oil sector portfolio with an aggregate value of $1000, is expected to have a quarterly return of $62.82 (6.282%) for the next period, with a standard deviation of plus or minus $82.40 (8.24%). Since the purpose of these portfolio calculations is to make predictions of likely next quarter portfolio performance, the distribution of the data will determine what types of predications can be made. Ideally, the data will be normally distributed (Keller, 2005). Figure 3 is a histogram of the individual quarterly stock rate of returns for the portfolio. The histogram presents the number of stocks within various quarterly rates of return ranges (from -25% to +25% at 5% increments). The Histogram shows the stocks' quarterly rates of return to be roughly normally distributed.

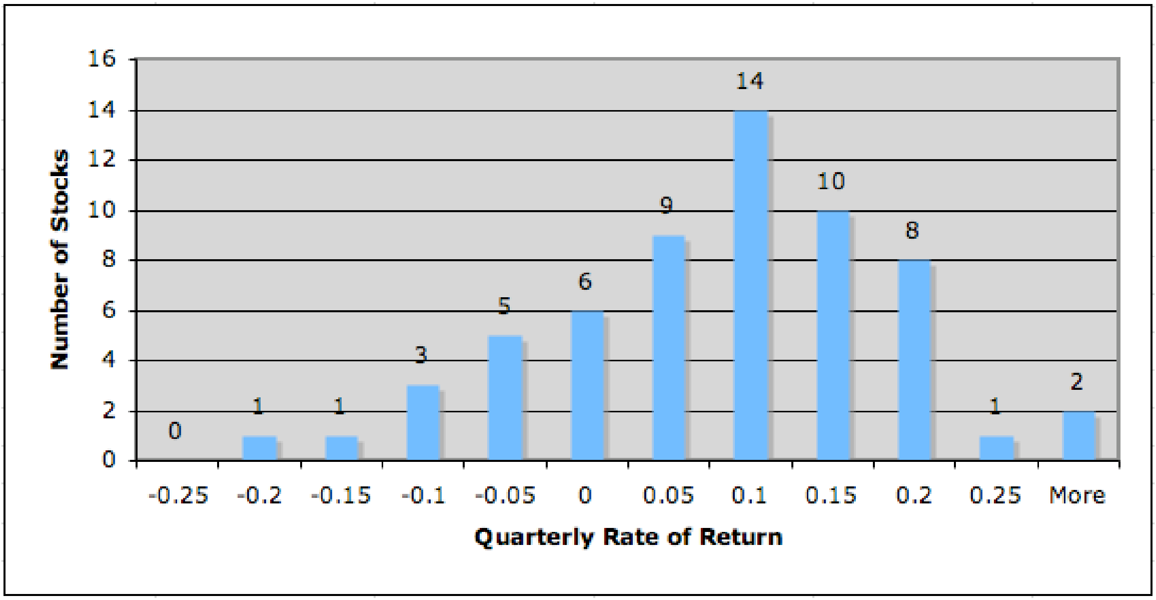

Figure 3. Histogram of Five-Stock Portfolio Quarterly Rates of Return

With the quarterly rates of return being normally distributed, the Empirical Rule from statistical theory can be applied, indicating that approximately 68% of the time the next quarterly return should fall within one standard deviation of the expected return, and 95% of the time the next quarterly return should fall within two standard deviations (Keller, 2005). Thus, with 95% confidence it is expected that the next equally weighted oil-sector portfolio quarterly return will fall somewhere between $-101.98 and $227.62.

6. Selection of a Portfolio Risk and Return Strategy

With the calculations that quantify stock performance completed, a portfolio strategy needs to be qualitatively defined. The qualitative strategy is then translated into quantitative risk and return values or goals. Since MPT is based on making trade-offs between risk and return, any portfolio strategy must address these two factors. For example, a portfolio manager may be serving investors who wish to be exposed to the least risk, while pursuing a particular portfolio rate of return. In this case, the portfolio's overall strategy would be to maintain the "fair" rate of return while pursuing the goal of minimizing risk. The

portfolio manager ultimately assigns a quantitative value to the qualitative term "fair" by fixing the portfolio's desired rate of return to a specific value (based on industry standards or professional judgment). Alternatively, the portfolio strategy could be to maximize the rate of return while accepting a set, quantified level of risk. Strategies that fix either the risk or return value implicitly assume that the desired return rests on the top part of the portfolio's Risk-Return curve. If the desired return is located on the underside of the portfolio's Risk-Return curve, an investor can improve the portfolio's return and lower the portfolio's risk by selecting the stock weighting which corresponds to the Risk-Return curve's inflection point. Figure 4 illustrates this point. For this five-stock example, a strategy of minimizing risk will be adopted.

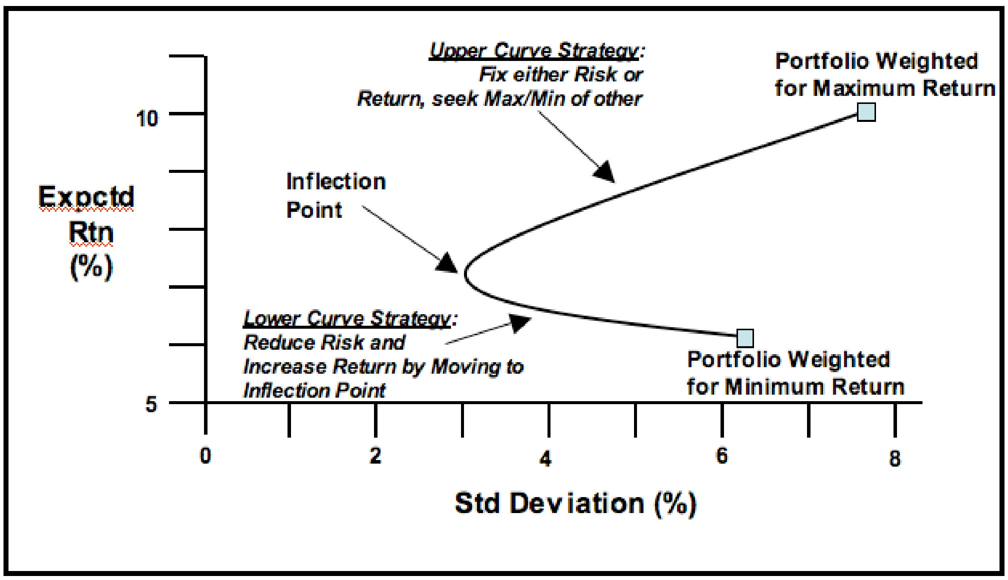

Figure 4. Portfolio Risk-Return Plot and Recommended Investment Strategies.

7. Optimization of the Portfolio

In keeping with the "minimize risk for a set rate of return" strategy proposed above (assuming 6.282% quarterly return is on upper curve), a quantitative value for portfolio's standard deviation is established, and portfolio manager can use non-linear programming optimization processes to vary the weightings of the stocks within the portfolio until the minimum risk for a given rate of return is found.

For the purposes of the oil sector portfolio example, it is assumed that a quarterly expected rate of return of 6.282 percent is desired for the portfolio (this happens to also be the previously computed quarterly rate of return for an equally weighted oil-sector portfolio). Although several available software packages allow users to create and solve non-linear program models, the ubiquitous nature of Microsoft Excel™ makes it a natural choice for relatively small portfolio analysis tasks. However, it is important to note that larger portfolios can exceed Microsoft Excel's™ variable limits or present "locally optimal" solutions (rather than the desired global maximum or minimum solution) due to the type of solver engine used by the software (Balakrishnan, Render & Stair, 2007).

In order to optimize the oil portfolio, the portfolio strategy must be translated into a suitable model, with defined Decision Variables (variables to be solved for), an Objective Function (defining the goal, maximize or minimize), and Constraints (limitations which must be observed by any solution). In the case of the oil stock portfolio, the model's Decision Variables are the dollar weightings, W_1 through W_5 as previously defined, for each of the stocks within the portfolio.

The portfolio strategy for this oil sector example fixes the quarterly return and seeks to minimize the portfolio's risk. The Objective Function of the non-linear model must therefore describe mathematically how the portfolio's variance is calculated in terms of the Decision Variables. Specifically, for this example, the risk minimizing Objective Function is:

$$\begin{aligned}\mathbf{Var_{Port}} = {} & W_1^2\sigma_1^2 + W_2 2^2\sigma_2^2 + W_3^2\sigma_3^2 + W_4^2\sigma_4^2 + W_5^2\sigma_5^2 + 2(W_1W_2\mathrm{cov}_{12}) \\ & + 2(W_1W_3\mathrm{cov}_{13}) + 2(W_1W_4\mathrm{cov}_{14}) + 2(W_1W_5\mathrm{cov}_{15}) + 2(W_2W_3\mathrm{cov}_{23}) \\ & + 2(W_2W_4\mathrm{cov}_{24}) + 2(W_2W_5\mathrm{cov}_{25}) + 2(W_3W_4\mathrm{cov}_{34}) + 2(W_3W_5\mathrm{cov}_{35}) \\ & + 2(W_4W_5\mathrm{cov}_{45})\end{aligned}$$

For calculation convenience, the Objective Function minimizes the variance of the portfolio, with the knowledge that the square root of the minimum variance will also yield the minimum portfolio standard deviation.

The constraints within which the non-linear model must operate are also specifically defined. First, the weighting of the various portfolio stocks must be non-negative, since without this constraint a negative stock weighting solution could result, having no common physical meaning. This is handled within Microsoft Excel™ by choosing the "assume non-negative" selection in the model options. Second, the individual weightings of each stock must sum to the whole. In other words, since the portfolio dollar value is 100 percent (1.0) of the portfolio's value by definition, the sum of the individual stock weightings must add up to the portfolio dollar value. This can be expressed mathematically as:

$$\mathbf{W_1 + W_2 + W_3 + W_4 + W_5 = 1}$$

And finally, the expected quarterly rate of return for the portfolio has been set by the portfolio strategy at 6.282%. This is expressed mathematically using the formula for the expected rate of return for a portfolio where the weighting of each stock is multiplied by its individual expected quarterly rate of return and these individual products summed:

$$\mathbf{E(R)_{Port} = 0.06282 = W_1(0.0543)+W_2(0.0582)+W_3(0.0486)+W_4(.0404)+W_5(0.1399)}$$

With the Decision Variables, Objective Function, and Constraints defined, the model can be entered into Microsoft Excel.™ The formulas expressing the relations between the various variables and equations are entered, and the Solver function activated to produce a set of individual stock weightings giving the minimum portfolio risk while achieving the desired portfolio quarterly rate of return.

Finally, the portfolio manager verifies that the limitations of Microsoft Excel™ mentioned previously, do not affect the calculated solution. While there is no way to change the variable limit within Microsoft Excel,™ the Solver will alert the portfolio manager that its variable capacity has been exceeded. For this model no variable limitations were encountered. The potential for the software to return locally optimal solutions can be minimized by the portfolio manager

entering different Decision Variable initial values and comparing the Solver software's results to determine whether different solutions were found and which solution has the highest maximum or lowest minimum (Balakrishnan, et al., 2007). For this model, entries of different initial values for the Decision Variables yielded the same solution.

For the example of the oil-sector stock portfolio, the optimized dollar value weightings were: a 18.8 percent weighting for Exxon Mobil (XOM), a 7.6 percent weighting for Baker Hughes International (BHI), a 0.0 percent weighting for Chevron, a 55.0 percent weighting for Royal Dutch Shell, and an 18.5 percent weighting for Valero (VLO). This portfolio is expected to produce a quarterly rate of return of 6.282 percent, with a minimized risk (standard deviation) to the quarterly rate of return of 7.26 percent. Stated in other terms, there is 95 percent confidence that the next quarterly rate of return will be within plus or minus two standard deviations of the expected rate of return, or within the range of -8.24 to 20.8 percent. Comparing this to the equally weighted portfolio's identical expected quarterly rate of return of 6.282 percent, standard deviation of 8.24 percent, and 95 percent confidence of a quarterly rate of return between -10.20 to 22.76 percent, it is apparent that the optimized portfolio weighting has a lower risk of a lower rate of return (-8.24%) than the initial portfolio (-10.20%).

B. EVM DATA SET

In order to use the financial analysis demonstrated in the stock example above on a government portfolio, a suitable government portfolio must be identified. With a representative government portfolio identified, EVM data for the portfolio components must be located, collected, and described. Finally, potential methods for converting the EVM raw data into data analogous to the "rate of return" measure of the stock example will be examined, and a suitable metric selected.

1. Selection of Representative Government Portfolio

As in the oil-sector stock portfolio presented above, it is necessary to select a representative government sector upon which to conduct the proposed analysis. Because Congress provides public funds annually to the various federal departments and agencies through Appropriations Bills signed into Law by the President, it is common for federal departments and agencies to mirror the appropriation categories Congress establishes in the law to fund various programs and projects. This mirroring allows the government financial manager to manage the inherent restrictions on purpose, time, and amount established by Congress for each type of appropriation. Thus, the Department of the Navy may assign a financial manager for all Aircraft Procurement, Navy (APN), Ship Construction, Navy (SCN), or Other Procurement, Navy (OPN) programs identified in these appropriations.

For the purposes of this research, it is only necessary to select an appropriation category likely to have Earned Value Management data available. The Department of Defense requires that programs valued over $73 million in Research, Development, Test and Evaluation (RDT&E) or over $315 million in procurement (Fiscal Year 2000 constant dollars) collect and use Earned Value Management System data (DoDD 5000.2, 2003). Since most procurement appropriations are acquisition programs, the selection of any procurement category would likely be suitable. Therefore, this research arbitrarily selects the Aircraft Procurement, Navy (APN) appropriation category as the government sector to be examined.

To demonstrate the application of financial portfolio analysis to APN, while limiting the complexity and scope of this research, five programs from within the APN acquisition portfolio will be selected for analysis. Again, the selection of programs within the APN category is arbitrary, since this research seeks to demonstrate the feasibility of such analysis within a manageable scope for both the reader and researcher. Furthermore, in order to avoid distraction and to

avoid the potential for unintended interpretation of this research, the five APN programs selected will only be identified as Programs A through E.

2. EVM Data Source

The required EVM data for the five APN programs selected were downloaded from the Defense Acquisition Management Information Retrieval (DAMIR) system sponsored by the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics/Acquisition Resources and Analysis (the Defense Acquisition Management Information Retrieval [DAMIR], 2007). Other potential sources of EVM data considered included: Defense Contract Management Agency (DCMA) EVM data collected during contract administration, and the Defense Automated Cost Information Management System (DACIMS) developed and maintained by the Defense Cost and Resource Center (DCARC).

DCMA as a source of EVM data was rejected because no centralized database of such data was found. Rather, EVM data had to be collected from the various DCMA field activities responsible for an individual program's contract oversight. Identifying and establishing the requisite working relationships necessary to collect the required data was viewed as too difficult for the limited scope of this research. Use of this data source by a government financial manager would be more time-consuming given the larger portfolios involved.

EVM data from DACIMS were rejected because of the location and format of the data. While EVM data were at least partially available within the Contractor Cost Data Reporting (CCDR) documents maintained by the site, collection required the opening of multiple text documents where the requisite data could then be stripped out and placed into a specially created database. Again, the time and complexity of EVM data retrieval, made this option unappealing both for the limited scope of this research and by a government financial manager in support of a larger portfolio. Of note, however, DACIMS is sponsoring a pilot EVM data repository site which may be a valuable source in the future.

In contrast, the DAMIR database provides a top-level management EVM data purview for a large number of Department of Defense Acquisition programs. The DAMIR site provides the ability for authorized users to view acquisition program EVM data by program name or contract number. DAMIR logically groups related contracts, such as aircraft engine, airframe, and avionics, into “portfolios” where individual contracts can be selected for EVM data display. The various program EVM data maintained in DAMIR are structured and presented in the same manner for all programs. DAMIR EVM data are reported on a quarterly rather than monthly basis which is less than optimal, but manageable within the context of this research. Ideally, a monthly EVM database is desired.

DAMIR EVM data consists of quarterly reports containing: date, Budgeted Cost of Work Scheduled (BCWS), Budgeted Cost of Work Performed (BCWP), Actual Cost of Work Performed (ACWP), Schedule Variance (SV), Cost Variance (CV), Percent Complete, Estimate at Completion (EAC), and several other related fields. Selected EVM data elements for the five arbitrarily selected APN programs are presented in Tables 4 through 8.

3. EVM Data Element Description

The data elements presented in Tables 4 through 8 were each selected for inclusion for various reasons. The Report Date provides the necessary interval framework within which to place all other data. Without date information, rates could not be calculated. The BCWS, BCWP, and ACWP data are the key EVM metrics used to capture change. Various differences and ratios of these three metrics are used to quantify status and predict future trends. The Schedule Variance (SV) metric quantifies the difference between the cost of the work scheduled and the cost of the actual work performed. While SV can be derived from the key EVM metrics (SV=BCWP-BCWS) (Defense Acquisition University [DAU], 2005), it is included in the summary tables for ease of reference.

Similarly, Cost Variance (CV) measures the difference between the cost of the work performed and the actual amounts paid for the work (CV = BCWP - ACWP), and is also included for ease of reference.

Program A Contract Data Summary ($M)

Rpt Date	BCWS	BCWP	ACWP	SV	CV	% Comp	EAC
Feb-04	85.7	79.9	73.9	-5.8	6	4.88	1729.7
Apr-04	160.9	150.9	139.8	-10	11.1	8.93	1786.1
Sep-04	272.3	262.9	247.4	-9.4	15.5	15.58	1793.4
Dec-04	381.6	368.3	353.5	-13.3	14.8	21.58	1798.7
Feb-05	490.4	474.9	471.4	-15.5	3.5	27.18	1809.7
May-05	623.5	607.1	605	-16.4	2.1	35.05	1772.9
Jul-05	714.2	693.2	724.5	-21	-31.3	39.42	1794.4
Nov-05	906.4	882	935.4	-24.4	-53.4	50.1	1798.6
Feb-06	166	166			166		
Feb-06	1018.9	979.9	1066.1	-39	-86.2	50.56	2024.9
Apr-06	1083.4	1049	1150.9	-34.4	-101.9	54.31	2024.9
Aug-06	1229.8	1196.9	1307.8	-32.9	-110.9	65.24	2024.9
Nov-06	1336.4	1298.7	1421.5	-37.7	-122.8	70.64	2021.7

Table 4. EVM Data Elements Program for A (After Defense Acquisition Management Information Retrieval Purview, Office of the Under Secretary of Def. for Acquisition, Technology and Logistics [DAMIR], March 2007).

Program B Contract Data Summary ($M)

Rpt Date	BCWS	BCWP	ACWP	SV	CV	% Cmp	EAC
Apr-04	2210.2	2191.5	2173.1	-18.7	18.4	61.93	3652.9
Jun-04	2470.7	2449.3	2416.2	-21.4	33.1	69.27	3652.9
Sep-04	2878.8	2860.6	2811.8	-18.2	48.8	57.06	5138
Dec-04	1540.2	1541.6	1488.1	1.4	53.5	47.62	3344.5
Mar-05	1722.9	1716	1633.6	-6.9	82.4	56.41	3119.9
Jun-05	2048.5	2055.2	1962.3	6.7	92.9	67.57	3078.1
Sep-05	2389.5	2382.7	2270.6	-6.8	112.1	78.29	3041.8
Dec-05	1121.8	1106.1	1042.7	-15.7	63.4	75.81	1460
Mar-06	86.2	92.9		6.7	92.9		
Mar-06	1323.9	1321.5	1258.1	-2.4	93.4	90.51	1443.2
Jun-06	1403.5	1397.2	1340	-6.3	57.2	96.43	1424.9
Sep-06	1427.8	1421.2	1367.4	-6.6	53.8	99.41	1421.2

Table 5. EVM Data Elements for Program B (After DAMIR, 2007).

Program C **Contract Data Summary** **($M)**

Rpt Date	BCWS	BCWP	ACWP	SV	CV	% Cmp	EAC
Initiation	-	-	-	-	-	-	-
Jan-05	113.5	108.8	106.7	-4.7	2.1	0.98	880.2
Mar-05	245.9	240.6	232.7	-5.3	7.9	1.01	881.8
Jun-05	402.9	384.2	379.1	-18.7	5.1	0.97	889
Dec-05	456.1	448.9	442.9	-7.2	6	1	996.3
Mar-06	518.9	510.8	508.2	-8.1	2.6	0.99	908.3
Jun-06	589.5	581.6	579.6	-7.9	2	0.99	913.3
Oct-06	635.4	625.3	626.4	-10.1	-1.1	0.98	915.2

Table 6. EVM Data Elements for Program C (After DAMIR, 2007).

Program D **Contract Data Summary** **($M)**

Rpt Date	BCWS	BCWP	ACWP	SV	CV	% Cmp	EAC
Jan-04	3830.3	3788.1	3777.7	-42.2	10.4	87.12	4391.2
Apr-04	3910.6	3857.7	3860.3	-52.9	-2.6	88.68	4425.7
Sep-04	4036.9	3980.2	3963	-56.7	17.2	92.79	4364.5
Dec-04	4061.7	4019.4	4004.5	-62.3	14.9	93.95	4353.1
Mar-05	4123.9	4080.2	4050.8	-43.7	29.4	95.36	4343.1
Jun-05	4157.9	4118.2	4092.1	-39.7	26.1	96.01	4412.5
Sep-05	4196.7	4154	4126.7	-42.7	27.3	96.64	4450.3
Dec-05	4221.5	4179	4166.2	-42.5	12.8	97.11	4428.4
Jan-06	-12.5	6.1		18.6	6.1		
Mar-06	4237.9	4216.9	4198.9	-21	18	95.85	4464.8
Jun-06	4269.4	4253.7	4231.8	-15.7	21.9	96.63	4467.9
Sep-06	4294.9	4272.3	4262.2	-22.6	10.1	96.8	4460

Table 7. EVM Data Elements for Program D (After DAMIR 2007).

Program E **Contract Data Summary** **($M)**

Rpt Date	BCWS	BCWP	ACWP	SV	CV	% Comp	EAC
Jan-04	1437.2	1428.2	1432.7	-9	-4.5	35.43	4219.9
Apr-04	1631.9	1617.9	1634.4	-14	-16.5	39.85	4219
Jul-04	1824.8	1797.9	1817.3	-26.9	-19.4	43.45	4269.2
Sep-04	1931.3	1908.1	1921.1	-23.2	-13	45.94	4269.2
Mar-05	2261.4	2229	2265.9	-32.4	-36.9	52.84	4269.2
Jul-05	2480.4	2441.7	2511.9	-38.7	-70.2	56.75	4439.7
Oct-05	2606.9	2594.6	2695.6	-12.3	-101	51.73	5061.8
Jan-06	2951	2892.3	3013.9	-58.7	-121.6	58.21	5180.5
Jun-06	3139.2	3077.2	3221.7	-62	-144.5	61.6	5225.9
Sep-06	3339.7	3252.9	3412	-86.8	-159.1	65.44	5234.7

Table 8. EVM Data Elements for Program E (After DAMIR, 2007).

Project Percent Complete (% Cmp) values are taken directly from DAMIR and are included as a measure of the program's maturity and to provide a data source, which might be used to derive additional information not provided. Finally, Estimate At Completion (EAC) values are also taken directly from DAMIR as representative of the final predicted cost and as an additional data source for information otherwise not provided. Notably missing from the selected data and the DAMIR database is program Budget At Completion (BAC) data. The BAC is the overall planned cost of the program and is the sum of all the Work Breakdown Structure (WBS) BCWS values. The BAC may change over time as the planned scope of program work is increased or decreased.

4. EVM Data Element Differences

There are some differences in the EVM data elements' content as presented in Tables 4 through 8. With regard to report date, although each of the programs generally reports quarterly, the actual months vary from program to program and even within individual programs. For example, Program A (Table 4) initially reports in February, April, September, and December while Program E (Table 8) reports in January, April, July, and September. Even within Program A, the third quarter of the year is variously reported in September, July, and August. Finally, Program E does not contain quarterly data for either January 2005 or March 2006.

For the three-year period covered, each of the five programs is at a different stage. Programs B (Table 5) and D (Table 7) are established programs as evidenced by their percent completion values which start at over fifty percent and end in the high ninety percent range. During the same period, Program A (Table 4) was initiated and has reached seventy percent completion. As a newly initiated program, Program C (Table 6) has less than three years of data and ends the period only one percent complete. Program E (Table 8) is in mid-stream during the period, ending at about two-thirds complete.

Additional data differences include the addition of adjusting entries and an apparent resetting of some program EVM data. Programs A, B, and D (Tables 4, 5, and 7) have adjusting entries made to their EVM data. Entries in the Spring of 2006 for these three programs appear to capture one-time WBS changes and associated earned value amounts. In addition to the adjusting entry, Program B (Table 5) also appears to reset (or re-baseline) its EVM data at the end of each year, as evidenced by the lowering of the BCWS, BCWP, ACWP, and percent complete values for the program. In order to provide meaningful comparison, methods will have to be developed to “normalize” these differences.

C. EVM DATA METHODOLOGIES

In order to apply financial portfolio analysis techniques to the selected government portfolio and its associated EVM data, program EVM data must be normalized, a return measure must be identified, a risk measure must be established, and an appropriate portfolio strategy must be developed.

1. EVM Data Normalization

In order to standardize the available EVM data and correct for the differences in the data elements noted above, the EVM data must be converted, or “normalized.” Specifically, the varying reporting period durations will have to be normalized, a scheme for dealing with adjusting entries devised, a method for dealing with program resets, or re-baselining, developed, and a method of aligning quarters for correlation computations established.

Because the collected EVM program data are largely quarterly data, the periods that are longer or shorter than the standard three-month quarter must be normalized to a three-month period to ensure accurate comparison. For example, Program E (Table 8) has several different periods within the first five entries. Program E EVM line data are recorded for January, April, July, September, and March. Assuming that each data line entry corresponds to the same day of the month (i.e., the last day), there are three months between line

one and two data, three months between lines two and three, two months between lines three and four, and six months between lines four and five. In order to establish equivalence between lines, any calculations involving differences between lines must be divided by a “period normalization factor” determined by dividing the number of months between entries by three (the standard period). For instance, the difference between CVs from lines three and four would be divided by a ”period normalization factor” of two-thirds (two months divided by the standard three months) in order to ensure equivalent quarterly difference values. This research will normalize EVM data for differences between periods as described above.

The adjusting entries found in Programs A, B, and D (Tables 4, 5, and 7) must also be accounted for. These entries either increase or decrease BCWS, BCWP, or ACWP and accordingly reflect in the SV and CV elements as well. Although the DAMIR database does not indicate why these changes were made, for the purposes of this analysis it is only important that any effect on program performance is captured. Program D (Table 7) provides an adjusting example in January 2006 when the program’s BCWS is reduced by 12.5 and the BCWP is increased by 6.1. Accordingly, the SV (BCWP-BCWS) is increased by 18.6 (6.1 - (12.5)) and the CV (BCWP-ACWP) is increased by 6.1 (6.1 - 0). An examination of the BCWS, BCWP, and ACWP data shows that all values are increasing with every subsequent report, indicating that the data are cumulative. With cumulative data, the adjusting entries are captured in the subsequent reporting period’s period data and, therefore, do not have to be dealt with separately. The separate line entry is most likely included for higher-level visibility of program changes and record-keeping. For this research adjusting entries will be deleted prior to conducting the analysis.

Next, a methodology for dealing with the resetting, or re-baselining, of program EVM data must be addressed. Re-baselining is a major programmatic issue, since most are due to poor performance and, or unrealistic baselines (plans). Unfortunately, resetting or re-baselining occurs often enough that excluding programs with re-baselining may be too simplistic, leading to questions

of whether this research can be more broadly applied. Accordingly, an inclusive method that minimizes analytical distortion is desired. In order to more fully demonstrate the issue and potential solutions, the following example is presented.

A particular monetary unit is experiencing annual inflation at a rate of 50 percent per year. After 11 years, it takes almost 100 monetary units to equal the value of one monetary unit 11 years earlier. The government decides to revalue the monetary unit in the eleventh year, decreeing that 100 monetary units will be traded in for one new monetary unit. Assuming inflation remains at 50 percent for the next four years, how can the yearly inflation trend be accurately represented? Using yearly differences in value divided by the previous year's monetary value gives the annual inflation rate. Direct application of this measure would produce 50 percent inflation values for years one through eleven, a 99 percent deflation in year twelve, and 50 percent rates in years thirteen through fifteen. Averaging the annual values gives an average inflation rate of approximately 41 percent, despite the fact that inflation has actually been 50 percent per annum for the entire period.

Alternatively, the values observed prior to the revaluation can be converted to what they would have been had the revaluation occurred earlier. The values of years one through ten would be divided by 100 and the yearly inflation calculations recomputed. This method yields an annual rate of inflation of 50 percent per year rate, and the correct average rate of 50 percent. This is straightforward when the revaluation is explicit. However, if the government revalued the monetary unit and changed its "functionality" at the same time, this method could become extremely difficult. For example, if the government revalued the monetary unit and at the same time no longer allowed food purchases to be made with it, the recalculation of previous year's values would be difficult because part of the previous years' monetary value was its ability to purchase food.

A final possibility would be to simply exclude the "one-time" revaluation year when calculating the yearly rate of inflation. Thus, years one through ten would have 50 percent inflation, year eleven would have no calculated rate, and years' twelve through fifteen would have 50 percent rates. An average of the calculated values (excluding the uncalculated year) would also yield the correct average of 50 percent. The one drawback with this method is that if the revaluation year actually had a different inflation rate, this method would discard this information as well as the effect of the revaluation. The simplicity of this method, especially when the revaluation is accompanied by a change in functionality, outweighs the potential drawback.

The yearly number of monetary units in the example above, is simply the "then year dollar" amount required to purchase the same initial year "value" in the current year. Program EVM data is reported in the same "then year dollar" format making the analogy straightforward. However, the conversion of current and past year data into rate measures (to be discussed in the next section) before comparing data year to year eliminates the need for a consistent dollar baseline between years (although all data within a period must have a consistent dollar measure). With this example in mind, dealing with program re-baselining can be considered.

Ideally, program re-baselining occurs infrequently when a program's scope is significantly changed by performance or external factors which make the measurement of progress against the original baseline (plan) questionable; however, these changes may also occur due to limitations in the EVM tracking system or for program management related reasons. Program B (Table 5) has two EVM data resets in the period of interest- first in December 2004 and again in December 2005. An examination of previous data within DAMIR indicates that this is an annual reset, but gives no further information on the nature or reasons for the reset.

With certain assumptions, the "pre-re-baselining" EVM data could be adjusted as in the monetary example above. The key assumption for such an

adjustment would be that the earned value, or BCWP, has not physically changed between the periods, but was merely programmatically adjusted. Unfortunately, adjustments to EVM data are usually driven by significant external programmatic requirements that do not necessarily reflect the value of work performed in the current period or previously. Additionally, functionality and, or requirements changes are often part of a program re-baseline. Thus, since any straightforward adjustment of previous data would assume that previous work was performed to meet current requirements, this method does not appear to be desirable.

Alternatively, the periods of discontinuity could simply be ignored when performing the requisite portfolio analysis. Using this methodology, any calculations comparing previous data to re-baseline period data would be discarded and not used in subsequent calculations. This method removes the impact the large downward resets would have on return and risk calculations (i.e. lowering overall return and raising risk), instead focusing on performance differences within continuous periods. It could be argued that re-baselined programs are obviously performing poorly, since they would likely not be reset otherwise, and therefore all the data, discontinuous or not, should be used. However, since these are external programmatic decisions and the portfolio manager is concerned with program performance within the portfolio, the exclusion of period discontinuities is likely to paint a more accurate picture of the program's performance within the portfolio. It should be noted that the reduction in the available data when the discontinuities are removed will affect the calculated return and risk values, since the data set is smaller; however, the risk and return measures should be more indicative of the program's actual performance. Therefore, this research will discard discontinuous or unique period EVM data in accordance with the method described above.

Finally, a method for aligning program quarters for correlation calculations must be established. Because correlation calculations are meant to quantify how programs vary in relation to each over the same period of time, a standard time period must be established. Since the most recent three years of data were

selected for analysis, each year will be broken into a first, second, third, and fourth quarter. Programs with data for January, February, or March will be assigned to the first quarter of the appropriate year, programs with data for April, May, and June assigned to the second quarter, and so on. Quarters where no data are available will be left blank, and the corresponding co-variance calculations will not be performed. The average co-variance values will be computed using only the available number of co-variance data points.

2. Defining an EVM Return Measure

Given the standardized and normalized EVM data available for the five acquisition programs in the government portfolio, a suitable measure of program performance, or return, must be selected.

EVM data are being used in this research due to their relationship with individual program performance and its availability. As previously mentioned, one of the primary hurdles government financial managers face in attempting to apply MPT-based portfolio analysis is the lack of accessible, periodic data on individual program performance. Government acquisition requirements specify that EVM data be collected for the specific purpose of government monitoring and management of program performance. Thus by definition, EVM data are related to program performance. The steady growth of internet-based databases continues to increase EVM data accessibility. While EVM data have been accessible through various documents such as CPRs and CCDRs, gaining access to these documents has required coordination with numerous government entities and a significant "data-mining" time investment. Online EVM databases now allow relatively easy access to a wide range of program data. These sources still tend to be relatively "grainy," containing quarterly vice monthly data populated from different sources, but they do provide access that was previously lacking.

It is also critical to recognize that while EVM data are being used, many of the specific EVM measures used by program managers are not relevant for

portfolio analysis. While the program manager uses EVM data to identify, understand, and correct issues affecting program performance, the program portfolio manager uses EVM data to quantify program performance over time and compare these trends with other programs within the portfolio. For example, while a program manager may use CV, SV, Percent Cost Variance (%CV), Percent Schedule Variance (%SV), Cost Performance Index (CPI), Schedule Performance Index (SPI), and other metrics to detect, quantify, analyze, predict, and correct program variances, the portfolio manager simply requires an overall measure to quantify the trends in cost and schedule. The portfolio manager is not concerned with "fixing" programs. The portfolio manager assumes that program managers are continually taking action to get the best performance possible from their programs. Thus, the EVM metric sought by the portfolio manager is one that captures overall program schedule and cost performance over time.

At the practical level, the typical government program portfolio is defined by organization and appropriation, and has a portfolio financial manager assigned to facilitate and monitor the flow of funds into and out of the portfolio. These government financial managers typically have two tasks: first, ensuring for the proper accounting and administration of portfolio funds, and second, making recommendations for program funding adjustments to meet directed portfolio funding changes. An example of this second task would be direction to identify, by program and amount, cuts totaling some specified dollar amount to be shifted out of the portfolio to meet some higher priority requirement. Conversely, the portfolio financial manager might be asked to identify, by program and amount, where additional funds might be expended within the portfolio. To accomplish this task, the financial manager conducts some form of risk and return analysis in order to arrive at a recommendation. With an understanding of why and to what end a program portfolio manager desires to use EVM data for portfolio analysis, potential portfolio EVM measures can be examined.

One potential EVM measure for cost performance might be derived from the total actual cost of a program, as measured by the program's Estimate At

Completion (EAC). Calculating the difference between quarterly EACs and dividing by the earlier of the two EACs would yield a quarterly cost “rate of return” for the program. This technique is elegant in that the substitution of EAC for “stock price” seems intuitively logical, since both stock price and the EAC represent accepted measures of total value or cost. This measure also captures total program performance, since the EAC is derived from both cost and schedule measures. However, an examination of the available program EVM data raises questions as to whether the EAC data provided are accurate enough to use.

An inspection of the EAC data provided by Program A (Table 4) for the most recent year shows no change in EAC for the first three quarters and a decrease in the fourth quarter- although the SV and CV shrink and grow during the same period. From inspection, it appears likely that the EAC provided is either: not updated regularly; not calculated using the same quarterly BCWS, BCWP, or ACWP data reported in DAMIR; or that judgment or expertise adjustments have been used in determining the reported EAC.

In order to confirm the inaccuracy in the reported EAC data and to potentially calculate a more useable EAC, a re-calculation of the EAC from the core EVM data is attempted. Employing the Defense Acquisition University “Gold Card” EVM specified formula (DAU, 2005),

EAC = ACWP + ((BAC – BCWP)/(BCWP/ACWP))

encounters the immediate problem of the lack of an available BAC value. To attempt to derive a BAC for use in the EAC formula, the DAU Percent Complete formula (DAU, 2005) was rearranged to solve for BAC:

% Complete = (BCWP / BAC) * 100 becomes:
BAC = (BCWP / % Complete) * 100

When this calculation is performed for Program A for different quarters, the computed program BAC is not constant, but varies. Table 9 provides the required EVM data and BAC results, including the average BAC and standard deviation.

Date	BCWP	% Cmp	BAC	DEV^2
Feb-04	79.9	4.88	1637.3	18105.0
Apr-04	150.9	8.93	1689.8	6730.6
Sep-04	262.9	15.58	1687.4	7128.4
Dec-04	368.3	21.58	1706.7	4248.0
Feb-05	474.9	27.18	1747.2	605.6
May-05	607.1	35.05	1732.1	1580.3
Jul-05	693.2	39.42	1758.5	178.3
Nov-05	882	50.1	1760.5	129.3
Feb-06	979.9	50.56	1938.1	27636.9
Apr-06	1049	54.31	1931.5	25489.6
Aug-06	1196.9	65.24	1834.6	3938.9
Nov-06	1298.7	70.64	1838.5	4439.2
		Ave:	**1771.8**	8350.8
			Std Dev:	**91.4**

Table 9. Calculation of BAC for Program A.

From Table 9 it is apparent that the BCWP and Percent Complete data are independently determined leading to a varying BAC value. A potential cause for this inconsistency could be that the method used to determine Percent Complete varies from the method used to calculate BCWP. This could occur if BCWP were determined using the 50/50 rule, while the Percent Complete was calculated by an assessment of WBS Work Package progress using different measures (i.e. number of units completed or expert opinion). Alternatively, since Percent Complete is a derived value, meaning that it is calculated from other metrics, it is possible that the calculation is performed periodically using data available to the program at the time, and this calculation (from different time period data) is drawn fro a different source than the other data in DAMIR.

In order to definitively reject EAC as a suitable portfolio analysis metric, the “average BAC” (a non-standard measure) calculated for Program A was used

to calculate the EAC (using the formula above). The resulting calculated Program A EAC values are shown in the second to last column of Table 10.

Date	BCWP	ACWP	% Cmp	EAC	BAC	Calc EAC	EAC Difference
Feb-04	79.9	73.9	4.88	1729.7	1637.3	1638.8	90.9
Apr-04	150.9	139.8	8.93	1786.1	1689.8	1641.5	144.6
Sep-04	262.9	247.4	15.58	1793.4	1687.4	1667.4	126.0
Dec-04	368.3	353.5	21.58	1798.7	1706.7	1700.6	98.1
Feb-05	474.9	471.4	27.18	1809.7	1747.2	1758.8	50.9
May-05	607.1	605	35.05	1772.9	1732.1	1765.7	7.2
Jul-05	693.2	724.5	39.42	1794.4	1758.5	1851.9	-57.5
Nov-05	882	935.4	50.1	1798.6	1760.5	1879.1	-80.5
Feb-06	979.9	1066.1	50.56	2024.9	1938.1	1927.7	97.2
Apr-06	1049	1150.9	54.31	2024.9	1931.5	1944.0	80.9
Aug-06	1196.9	1307.8	65.24	2024.9	1834.6	1936.0	88.9
Nov-06	1298.7	1421.5	70.64	2021.7	1838.5	1939.4	82.3
			Ave:	**1864.992**	**1771.8**	**1804.2**	**60.7**

Table 10. Calculation and Comparison of EACs for Program A.

The fifth column of Table 10 lists the DAMIR provided “de facto” values for EAC, the seventh column provides this research’s calculated EAC, and the eighth column displays the difference between the two.

Inspection of the Table 10 EAC values confirms that the EAC values provided by the program are not mathematically representative of the actual EAC. As can be seen, the calculated EAC values for Program A’s most recent year vary for each of the quarters, while the EAC values provided by DAMIR vary only in the last quarter. Since the BAC is found only in the numerator of the EAC equation, the differences between the calculated and provided EACs cannot be explained by simply having an incorrect BAC. Rather, it is likely that the EAC, like Percent Complete, is not updated regularly or using the same data as reported quarterly in DAMIR.

Independent of data consistency issues, using EAC may also be problematic due to its relatively long-term nature when compared to the government portfolio manager’s task of managing the current funding in flows and outflows. Total program cost, which EAC estimates, is driven largely by

Congressional, organizational, and Program Manager decisions rather than by marginal portfolio manager funding decisions. Referring to a stock example, using EAC as a “stock price” proxy may be like using a stock analysts’ “target price” (the estimated price of the stock one year) as the measure of performance. In rejecting EAC, this research now considers other measures of program rate of return which might be constructed using Cost and, or, Schedule measures.

Given the inconsistencies in the provided EAC data as well as other conceptual issues, the use of this data as a “stock price” proxy for the government portfolio is unsuitable. Accordingly, neither the provided nor the calculated EAC can be recommended as a suitable program performance metric.

An alternate program performance measure could be constructed using schedule performance data. The difference of the SV (BCWP – BCWS) between two periods could be divided by the planned work (BCWS) to calculate a rate of return for schedule performance, or Percent SV. While this measure provides useful information, it is of limited use to the government portfolio manager, since the portfolio manager has only one “control lever” – the ability to change the portfolio funding level and the relative distribution of funds within it. The schedule performance of a program behind schedule may not change because more money is allocated to it, especially if the program is not expending its current funds. This can occur because of technical difficulties or from delays beyond the program’s control. Similarly, the removal of funding may not affect schedule performance until funding is reduced enough to slow work further. Perhaps most importantly, this measure does not account for the actual expenditure of funds since it has no ACWP term. Thus, while a schedule rate of return measure could be used to aid portfolio management decisions, the measure provides no information regarding the rate of actual expenditures, which is the government financial manager’s primary task.

In contrast, a similar performance measure constructed using the program’s CV and BCWP contains an actual expenditure measure. A CV-based rate of return indicator directly reflects the effects of the portfolio manager’s

funding adjustments. This cost rate of return measure would use the CV difference (BCWP – ACWP) between two periods, divided by the planned cost of the work completed (BCWP) to calculate a rate of return for cost performance. While this measure is similar to the standard EVM Percent CV (%CV), it differs in two ways: it is not expressed as a percentage, and it measures the rate of change between periods, vice within a period. The cost performance of the portfolio is directly tied to the cost performance of the component programs through the portfolio risk and return calculations. Thus, financial portfolio analysis using a cost performance rate of return will provide portfolio-weighting recommendations likely to meet the portfolio's expenditure requirements. However, using the cost performance rate of return measure in isolation ignores additional EVM performance information of value to the portfolio manager, specifically schedule performance information, when making funding decisions.

Because the cost performance rate of return measure only considers a program's cost performance, the measure cannot distinguish between programs with the same cost rate of return, but different schedule performances. For example, all other factors being equal, a portfolio manager would favor a program ten percent over budget and on-schedule to a program ten percent over budget and ten percent behind schedule; because, while the current funding profiles are identical, the on-schedule program may finish sooner at less total cost. The cost performance rate of return measure answers the current funding question, but is mute on the longer-term cost requirements. In fact, using a solely cost rate of return-based measure only marginally exploits the power of EVM, and might be otherwise performed using program expenditure rate data.

In order to capture the value EVM in measuring overall program performance, a rate of return measure incorporating both cost and schedule is desired. Such a measure can be constructed using Cost and Schedule Variances compared to the work performed. As a rate metric, this measure would be calculated using the data from two periods to determine the change between periods. The calculation sums the SV difference (BCWP – BCWS) between a particular period (annotated by a subscript "2") and the previous

period (annotated by a subscript "1"), divided by the planned work for the period and the CV difference (BCWP – ACWP) divided by the work performed during the period:

$$\mathbf{R_{EVM} = (SV_2 – SV_1) / (BCWS_2 – BCWS_1) + (CV_2 – CV_1) / (BCWP_2 – BCWP_1)}$$
$$\mathbf{= (BCWP_\Delta – BCWS_\Delta) / BCWS_\Delta + (BCWP_\Delta – ACWP_\Delta) / BCWP_\Delta}$$

The first term of the expanded equation above is simply the cost performance rate of return measure and the second term the schedule performance rate of return measure, as described above. By summing these two measures, a rate of return reflecting the effects of both schedule and cost rates affecting a program are captured and used in the subsequent portfolio analysis. For convenience, this rate of return is subsequently referred to as the EVM rate of return (R_{EVM}).

The selection of R_{EVM} as a measure allows the program performance information resident in program EVM data to be incorporated into the portfolio analysis. The choice to sum cost and schedule performance rates of return, vice using some other mathematical relation (such as multiplying the rates together) is mandated by R_{EVM}'s meaning within the subsequent portfolio analysis. R_{EVM} should proportionately represent overall program performance. For instance, a program on-schedule and X percent over-budget, should have a rate of return higher than a program behind-schedule and X percent over-budget, and a program significantly under-budget and marginally ahead of schedule, should have a higher rate of return than a program significantly under-budget and on-schedule. Summing the cost and schedule performance rates of return gives this result. If the rates of return were multiplied, a program significantly over-budget and on schedule would have the same rate of return as a program significantly under-budget and fractionally behind schedule.

Finally, because R_{EVM} is a rate measure calculated between multiple periods, trends are reflected rather than just the most recent situation. Portfolio analysis using R_{EVM} does not attempt to answer why a trend exists, but simply what the trend is. A program which has been on-budget and on-schedule may

have the same expected rate of return as a program that has bounced ahead of and behind-schedule while remaining on-cost. The deviations in the two programs R_{EVM}, however, would indicate the additional risk inherent in one program over the other. It is up to the program manager to seek out and correct the root causes of this increased risk, the program manager's success in this matter will be captured within R_{EVM}. Because the R_{EVM} captures the relevant program performance information contained in EVM data, R_{EVM} will be the rate of return measure used for this research's EVM-based government portfolio analysis.

3. Defining an EVM Risk Measure

In the stock portfolio example, the accepted measure of risk was the variability of the observed rate of return quantified by the rate of return's standard deviation. Accordingly, the same measure of risk will be used in evaluating the EVM-based government portfolio.

4. Selection of an EVM Portfolio Risk and Return Strategy

The federal government faces risk and return issues just as private enterprises do; however, the goals of the government portfolio manager differ from a private-sector stock portfolio manager in several ways. For instance, the stock portfolio manager is tasked with obtaining a suitable return at an acceptable level of risk, while the government financial manager is tasked to properly track all portfolio funds and to ensure that the portfolio collectively expends a defined dollar amount (without going over). While a stock portfolio manager is rewarded for increasing the portfolio rate of return and, or lowering the portfolio's risk, the government financial manager is not similarly motivated. While stock portfolio managers are able to buy and sell discrete pieces of companies via stock, the government portfolio manager cannot buy and sell equivalent discrete pieces of government programs. Finally, while stock portfolio

managers typically have broad discretion in buying and selling stocks, government portfolio managers typically have little discretion in moving significant funds between programs.

These public/private-sector differences may explain why financial portfolio analysis has not been broadly applied to government portfolios; however, they do not present barriers to the actual mechanics of the quantitative analysis or diminish the potential value of optimizing the risk and return of a government portfolio. Indeed, government portfolio managers within the Department of Defense routinely perform risk and return trade-offs when faced with the requirement to cut the overall portfolio budget. Two commonly used ”risk and return” trade-off techniques are worth mentioning.

The first commonly used “risk and return” trade-off when faced with a budget cut is for the financial manager to simply make the requisite percentage cut across all programs in the portfolio (McCaffery & Jones, 2004). The risk and return thinking of this approach is straightforward, every program loses the same percentage rate of return and assumes the same percentage of increased risk. While this approach ignores differences between programs which might make cuts of different magnitudes desirable, it is quick and easy to apply and fairly defensible, especially for small percentage cuts.

The second common course of action is to identify portfolio programs not expending their funds at the rate foreseen and cutting the program for the amount of the current and projected spending rate shortfall (McCaffery et al., 2004). Again, the risk and return thinking here is clear; programs not expending funds at the planned rate are probably behind, lessening their return and increasing their risk. By reducing these programs, the overall portfolio performance should be no worse than the already developing trend. Additional benefits of this strategy are: that the expenditure rate data are readily available to the financial portfolio manager and that the reduction is tied to program performance (can the program spend money). However, as mentioned earlier, this approach does not recognize that the expenditure of funds in accordance

with plan does not mean that planned program work is being accomplished. It is entirely conceivable that program funds are expended regularly without producing the desired result.

While the existence of these “risk and return” strategies confirms that the government is interested in the idea of managing portfolio risk and return, both strategies are only loosely aligned to program performance and both methods fail to account for the potential benefits of evaluating each program in the context of the whole portfolio. The application of financial portfolio analysis contemplated by this research aims to allow the government portfolio manager to link funding decisions to program performance and to reap the benefit of program interactions within the portfolio.

In order to apply financial portfolio analysis, a portfolio strategy for risk and return must be defined. Given that government portfolio managers are tasked with and judged by their ability to closely meet, but not exceed expenditure targets, a portfolio strategy of minimizing the risk of overspending is warranted. To minimize portfolio risk, the initial portfolio’s expected rate of return must be calculated. Since government portfolios are largely defined and established by law or high-level policy, the desired rate of return will be assumed to be the current portfolio’s rate of return. In the case of the selected government portfolio, the dollar weightings for each of the programs within the portfolio are defined as follows:

W_A = portfolio weighting of Program A
W_B = portfolio weighting of Program B
W_C = portfolio weighting of Program C
W_D = portfolio weighting of Program D
W_E = portfolio weighting of Program E

To determine current portfolio weightings, the annual budgets of the five government programs are added up. Since annual program budget data are not readily available, the initial dollar value of the sum of the expenditures for each

program over the most recent year as determined by ACWP will be used. The dollar value of a program is determined by subtracting the most recent monthly ACWP from the ACWP for the same month of the previous year. Thus, the dollar value of Program A (Table 4) is, $1421.5 (Nov 06) minus $935.4 (Nov 05), or $486.1. For programs where same-month data for the previous year are not available, or where re-baselining occurs, the nearest appropriate month's ACWP is used and the resulting value divided by a "annualizing" factor calculated by dividing the number of months between the two ACWP values by the number of months in a year (12). Thus, the dollar value of Program B (Table 5, re-baselined) is, $1367.4 (Sep 06) minus $1042.7 (Dec 05), divided by the normalizing factor of 0.75 (9 months divided by 12 months), or $432.9.

Using the EVM data contained in Tables 4 through 8, program returns, risks, and co-variances were calculated and are presented in Table 11.

					Co-variances				
	Bgt	% Bgt	R_{EVM}	σ_{EVM}	A	B	C	D	E
Prgm A	486.1	0.24046	-0.16871	0.2062	0.42515	-0.00083	0.00142	-0.05618	0.01054
Prgm B	432.933	0.21416	0.01362	0.0941	-0.00083	0.00885	-0.00038	0.0246	-0.0006
Prgm C	185.475	0.09175	-0.01578	0.0806	0.00142	-0.00038	0.0065	-0.02828	0.00736
Prgm D	135.5	0.06703	0.07293	0.6079	-0.05618	0.0246	-0.02828	0.3697	-0.01363
Prgm E	781.527	0.3866	-0.07903	0.1009	0.01054	-0.0006	0.00736	-0.01363	0.01017
Total:	2021.54	Wtd Av:	-0.06476						

Table 11. Summary of Program Returns, Standard Deviations, and Co-variances.

Summing the product of each program's EVM rate of return and existing relative portfolio weight in accordance with the formula:

$$\mathbf{R_{EVMPort} = W_A(R_{EVM\text{-}A})+W_B(R_{EVM\text{-}B})+W_C(R_{EVM\text{-}C})+W_D(R_{EVM\text{-}D})+W_E(R_{EVM\text{-}E})}$$
$$\mathbf{= .240(-.169)+.214(.014)+.092(-.016)+.067(.073)+.387(-.079)}$$
$$\mathbf{= -0.0648 \text{ or } \underline{-6.476\%}}$$

The current five-program government portfolio has a rate of return ($R_{EVMPort}$) of negative 6.476 percent. This rate of return will be the base rate of return used in the subsequent analysis. Given that the computed rate of return is likely to lie on

the bottom of the portfolio Risk-Return curve, a strategy of improving return and lowering risk by moving toward the inflection point will be pursued.

D. EVM PORTFOLIO OPTIMIZATION MODELS

This research will use two models to optimize the five-program government portfolio. The first model will mirror the five-stock example portfolio seeking to find optimal program weightings within the portfolio that minimize risk while maintaining the current return. This largely unconstrained model will establish a standard for comparison of the second, constrained optimization model. The constrained optimization model is designed to more accurately model the limitations faced by government financial managers overseeing a portfolio of programs.

1. EVM Optimization Model

At least a negative 6.476 percent rate of return on the five-program government portfolio is desired, matching the current portfolio performance. The non-linear model's Decision Variables will be the weightings of the individual programs within the portfolio:

W_A = portfolio weighting of Program A
W_B = portfolio weighting of Program B
W_C = portfolio weighting of Program C
W_D = portfolio weighting of Program D
W_E = portfolio weighting of Program E

The model's Objective Function mathematically describes the five-program government portfolio's aggregate risk, and pursues a minimization strategy. The Objective Function is the portfolio variance and is:

$$
\begin{aligned}
\mathbf{Var_{Port}} = {} & W_A^2\sigma_A^2 + W_B^2\sigma_B^2 + W_C^2\sigma_C^2 + W_D^2\sigma_D^2 + W_E^2\sigma_E^2 \\
& + 2(W_A W_B cov_{AB}) + 2(W_A W_C cov_{AC}) + 2(W_A W_D cov_{AD}) \\
& + 2(W_A W_E cov_{AE}) + 2(W_B W_C cov_{BC}) + 2(W_B W_D cov_{BD}) \\
& + 2(W_B W_E cov_{BE}) + 2(W_C W_D cov_{CD}) + 2(W_C W_E cov_{CE}) \\
& + 2(W_D W_E cov_{DE})
\end{aligned}
$$

The square root of the variance of the portfolio will be taken to determine the portfolio's standard deviation.

The non-linear model constraints are defined as follows: the weighting of the various portfolio stocks must be non-negative, the determined weightings of individual programs must sum to the whole, and the expected quarterly rate of return for the portfolio must be greater than or equal to -6.476%. These constraints are expressed mathematically as:

$$W_A, W_B, W_C, W_D, W_E \geq 0$$

$$W_A + W_B + W_C + W_D + W_E = 1$$

$$R_{Port} \geq -0.06476 \geq W_A(-.169)+W_B(.014)+W_C(-.016)+W_D(.073)+W_E(-.079)$$

The Decision Variables, Objective Function, and Constraints are entered into Microsoft Excel,™ the linear model assumption is deselected, and the Solver function activated to produce a set of individual stock weightings giving the minimum portfolio risk while achieving at least the desired portfolio quarterly rate of return.

2. Constrained EVM Optimization Model

The constrained optimization model uses the same Decision Variables and the Objective Function as defined in the previous optimization model. However, this model must account for additional limitations typically placed on a government portfolio manager.

Typically, a government financial manager may be asked to recommend where funding can be reduced in order to meet higher priority, emergent needs.

These requests typically require a certain dollar value, or percent to be removed from the aggregate portfolio, with the portfolio manager tasked with recommending which programs to reduce. While the portfolio manager is asked to recommend reductions, further allocation recommendations are usually discouraged. In other words, the portfolio manager can cut, but not use the opportunity to redistribute (making additional cuts to some programs in order to add to others). Finally, because government programs have been approved and funded through established processes, dramatic program budget reductions are discouraged. In practice, this may be translated into a maximum allowable percentage of program reduction.

To demonstrate these limitations, this research will assume that a five percent overall portfolio reduction is sought, no programs may have funds added, and that no program can take more than a twenty percent cut from its annual budget. The required constraints are expressed mathematically as:

$\mathbf{W_A, W_B, W_C, W_D, W_E \geq 0}$ (non-negativity)

$\mathbf{-0.06476 \geq W_A(-.169)+W_B(.014)+W_C(-.016)+W_D(.073)+W_E(-.079)}$ (Return)

$\mathbf{W_A + W_B + W_C + W_D + W_E = 1}$ (Weightings must total)

$\mathbf{W_A \leq ((Orig\ W_A / (1 - Port\ \%\ Rdctn))}$ (no addition to programs)

$\mathbf{\leq ((.24046) / (1 - .05)) = 0.25316}$ |

$\mathbf{W_B \leq (.21416) / (1 - .05)) = 0.22543}$ |

$\mathbf{W_C \leq (.09175) / (1 - .05)) = 0.09658}$ |

$\mathbf{W_D \leq (.06703) / (1 - .05)) = 0.07056}$ |

$\mathbf{W_E \leq (.38660) / (1 - .05)) = 0.40625}$ |

$\mathbf{W_A \geq ((1 - Max\ Cut\ \%) / (1 - Port\ \%\ Rdctn))(Orig\ W_A)}$ (no cut > 20%)

$\mathbf{\geq ((1 - .20) / (1 - .05))(.24046) = 0.20249}$ |

$\mathbf{W_B \geq ((1 - .20) / (1 - .05))(.21416) = 0.18035}$ |

$\mathbf{W_C \geq ((1 - .20) / (1 - .05))(.09175) = 0.07726}$ |

$\mathbf{W_D \geq ((1 - .20) / (1 - .05))(.06703) = 0.05645}$ |

$\mathbf{W_E \geq ((1 - .20) / (1 - .05))(.38660) = 0.32556}$ |

The Decision Variables, Objective Function, and Constraints are entered into Microsoft Excel,™ the linear model assumption is deselected, and the Solver

function activated to produce a set of individual stock weightings giving the minimum portfolio risk while achieving at least the desired portfolio quarterly rate of return, while satisfying the specified constraints. Of note, the specified constraints could result in there being no solution meeting the specified requirements. In this case, incrementally reducing the rate of return constraint should allow a solution.

IV. DATA ANALYSIS AND RESULTS

In accordance with the methodology described above, the EVM data for the representative government five-program acquisition portfolio was normalized, the program statistical measures calculated, the portfolio co-variances computed, a theoretically optimum portfolio determined, and six constrained, locally-optimum portfolios determined.

The quantitative changes in portfolio risk and return between the initial portfolio and the optimized portfolios are presented. The effects of portfolio constraints on portfolio performance are discussed.

A. THE OPTIMIZED EVM GOVERNMENT PORTFOLIO

1. Calculation of Program Statistical Measures

Individual program statistical measures are presented in Tables 12 through 16, below. Each table contains: EVM data report date, period (number of months) between report dates, period normalization factor to convert to a standard three-month quarter, core EVM data (BCWS, BCWP, ACWP, CV, and SV), normalized Cost Variance and Schedule Variance rates of return (R_{CV} and R_{SV}), the EVM rate of return (R_{EVM}), computed deviations of R_{EVM}, and the determined R_{EVM} variances. The bottom of each table has calculated averages, with the average (or expected) program R_{EVM} and standard deviation highlighted.

Program A												
Rpt Date	**Period**	**Norm Fctr**	**BCWS**	**BCWP**	**ACWP**	**CV**	**SV**	**R_{CV} Norm**	**R_{SV} Norm**	**R_{EVM}**	**R_{EVM}-R_{Av}**	**$(R_{EVM}\text{-}Rav)^2$**
Feb-04			85.7	79.9	73.9	6	-5.8					
Apr-04	2	0.667	160.9	150.9	139.8	11.1	-10	0.1077465	-0.083777	0.0239699	0.1926771	0.037124466
Sep-04	5	1.667	272.3	262.9	247.4	15.5	-9.4	0.0235714	0.0032316	0.026803	0.1955102	0.038224256
Dec-04	3	1.000	381.6	368.3	353.5	14.8	-13.3	-0.006641	-0.035682	-0.042323	0.1263842	0.015972977
Feb-05	2	0.667	490.4	474.9	471.4	3.5	-15.5	-0.159006	-0.030331	-0.189337	-0.020629	0.000425568
May-05	3	1.000	623.5	607.1	605	2.1	-16.4	-0.01059	-0.006762	-0.017352	0.1513554	0.022908448
Jul-05	2	0.667	714.2	693.2	724.5	-31.3	-21	-0.581882	-0.076075	-0.657957	-0.489249	0.239364864
Nov-05	4	1.333	906.4	882	935.4	-53.4	-24.4	-0.087791	-0.013267	-0.101059	0.0676485	0.004576316
Feb-06	3	1.000	1018.9	979.9	1066.1	-86.2	-39	-0.335036	-0.129778	-0.464814	-0.296106	0.087678946
Apr-06	2	0.667	1083.4	1049	1150.9	-101.9	-34.4	-0.34081	0.1069767	-0.233834	-0.065126	0.004241455
Aug-06	4	1.333	1229.8	1196.9	1307.8	-110.9	-32.9	-0.045639	0.0076844	-0.037955	0.1307527	0.017096269
Nov-06	3	1.000	1336.4	1298.7	1421.5	-122.8	-37.7	-0.116896	-0.045028	-0.161924	0.0067832	0.000046012
				Anl Bgt:	486.1		**Avg:**	-0.141179	-0.027528	**-0.16871**	0.00	0.042514507
											Std Dev:	**0.2062**

Table 12. Performance Calculations for Program A.

Program B												
Rpt Date	**Period**	**Norm Fctr**	**BCWS**	**BCWP**	**ACWP**	**CV**	**SV**	**R_{CV} Norm**	**R_{SV} Norm**	**R_{EVM}**	**R_{EVM}-R_{Av}**	**$(R_{EVM}\text{-}Rav)^2$**
Apr-04			2210.2	2191.5	2173.1	18.4	-18.7					
Jun-04	2	0.667	2470.7	2449.3	2416.2	33.1	-21.4	0.0855314	-0.015547	0.0699844	0.056367	0.003177244
Sep-04	3	1.000	2878.8	2860.6	2811.8	48.8	-18.2	0.0381717	0.0078412	0.0460129	0.0323955	0.00104947
Dec-04	3	1.000	1540.2	1541.6	1488.1	53.5	1.4					
Mar-05	3	1.000	1722.9	1716	1633.6	82.4	-6.9	0.165711	-0.04543	0.1202813	0.106664	0.011377208
Jun-05	3	1.000	2048.5	2055.2	1962.3	92.9	6.7	0.0309552	0.041769	0.0727242	0.0591069	0.003493624
Sep-05	3	1.000	2389.5	2382.7	2270.6	112.1	-6.8	0.058626	-0.039589	0.0190365	0.0054192	2.93673E-05
Dec-05	3	1.000	1121.8	1106.1	1042.7	63.4	-15.7					
Mar-06	3	1.000	1323.9	1321.5	1258.1	63.4	-2.4	1.056E-15	0.065809	0.065809	0.0521917	0.002723969
Jun-06	3	1.000	1403.5	1397.2	1340	57.2	-6.3	-0.081902	-0.048995	-0.130897	-0.144515	0.020884461
Sep-06	3	1.000	1427.8	1421.2	1367.4	53.8	-6.6	-0.141667	-0.012346	-0.154012	-0.16763	0.028099714
				Anl Bgt:	432.93		**Avg:**	0.0194283	-0.005811	**0.013617**	0.00	0.008854382
											Std Dev:	**0.0941**

Table 13. Performance Calculations for Program B.

Program C												
Rpt Date	**Period**	**Norm Fctr**	**BCWS**	**BCWP**	**ACWP**	**CV**	**SV**	**R_{CV} Norm**	**R_{SV} Norm**	**R_{EVM}**	**R_{EVM}-R_{Av}**	**$(R_{EVM}\text{-}Rav)^2$**
Initiation			-	-	-							
Jan-05			113.5	108.8	106.7	2.1	-4.7					
Mar-05	2	0.667	245.9	240.6	232.7	7.9	-5.3	0.0660091	-0.006798	0.0592115	0.0749867	0.005623006
Jun-05	3	1.000	402.9	384.2	379.1	5.1	-18.7	-0.019499	-0.08535	-0.104849	-0.089074	0.007934131
Dec-05	6	2.000	456.1	448.9	442.9	6	-7.2	0.0069552	0.1080827	0.1150379	0.1308131	0.01711206
Mar-06	3	1.000	518.9	510.8	508.2	2.6	-8.1	-0.054927	-0.014331	-0.069259	-0.053483	0.002860466
Jun-06	3	1.000	589.5	581.6	579.6	2	-7.9	-0.008475	0.0028329	-0.005642	0.0101335	0.000102687
Oct-06	4	1.333	635.4	625.3	626.4	-1.1	-10.1	-0.053204	-0.035948	-0.089151	-0.073376	0.005384065
				Anl Bgt:	185.48		**Avg:**	-0.010523	-0.005252	**-0.01578**	0.00	0.006502736
											Std Dev:	**0.0806**

Table 14. Performance Calculations for Program C.

Program D												
Rpt Date	**Period**	**Norm Fctr**	**BCWS**	**BCWP**	**ACWP**	**CV**	**SV**	**R_{CV} Norm**	**R_{SV} Norm**	**R_{EVM}**	**R_{EVM}-R_{Av}**	**$(R_{EVM}\text{-}Rav)^2$**
Jan-04			3830.3	3788.1	3777.7	10.4	-42.2					
Apr-04	3	1.000	3910.6	3857.7	3860.3	-2.6	-52.9	-0.186782	-0.13325	-0.320032	-0.392965	0.15442139
Sep-04	5	1.667	4036.9	3980.2	3963	17.2	-56.7	0.0969796	-0.018052	0.0789273	0.0059944	3.59326E-05
Dec-04	3	1.000	4061.7	4019.4	4004.5	14.9	-42.3	-0.058673	0.5806452	0.5219717	0.4490387	0.201635791
Mar-05	3	1.000	4123.9	4080.2	4050.8	29.4	-43.7	0.2384868	-0.022508	0.2159788	0.1430459	0.020462116
Jun-05	3	1.000	4157.9	4118.2	4092.1	26.1	-39.7	-0.086842	0.1176471	0.030805	-0.042128	0.001774768
Sep-05	3	1.000	4196.7	4154	4126.7	27.3	-42.7	0.0335196	-0.07732	-0.0438	-0.116733	0.01362659
Dec-05	3	1.000	4221.5	4179	4166.2	12.8	-42.5	-0.58	0.0080645	-0.571935	-0.644868	0.415855299
Mar-06	3	1.000	4237.9	4216.9	4198.9	18	-21	0.1372032	1.3109756	1.4481788	1.3752458	1.891301078
Jun-06	3	1.000	4269.4	4253.7	4231.8	21.9	-15.7	0.1059783	0.168254	0.2742322	0.2012993	0.040521399
Sep-06	3	1.000	4294.9	4272.3	4262.2	10.1	-22.6	-0.634409	-0.270588	-0.904997	-0.97793	0.956346672
				Anl Bgt:	135.5		**Avg:**	-0.093454	0.1663868	**0.072933**	0.00	0.369598104
											Std Dev:	**0.6079**

Table 15. Performance Calculations for Program D.

Program E												
Rpt Date	**Period**	**Norm Fctr**	**BCWS**	**BCWP**	**ACWP**	**CV**	**SV**	**R_{CV} Norm**	**R_{SV} Norm**	**R_{EVM}**	**R_{EVM}-R_{Av}**	**$(R_{EVM}\text{-}Rav)^2$**
Jan-04			1437.2	1428.2	1432.7	-4.5	-9					
Apr-04	3	1.000	1631.9	1617.9	1634.4	-16.5	-14	-0.063258	-0.025681	-0.088938	-0.009909	9.81793E-05
Jul-04	3	1.000	1824.8	1797.9	1817.3	-19.4	-26.9	-0.016111	-0.066874	-0.082985	-0.003955	1.5645E-05
Sep-04	2	0.667	1931.3	1908.1	1921.1	-13	-23.2	0.0871143	0.0521127	0.139227	0.2182568	0.047636021
Mar-05	6	2.000	2261.4	2229	2265.9	-36.9	-32.4	-0.037239	-0.013935	-0.051174	0.0278556	0.000775933
Jul-05	4	1.333	2480.4	2441.7	2511.9	-70.2	-38.7	-0.117419	-0.021575	-0.138994	-0.059964	0.003595739
Oct-05	3	1.000	2606.9	2594.6	2695.6	-101	-12.3	-0.201439	0.2086957	0.0072568	0.0862866	0.007445372
Jan-06	3	1.000	2951	2892.3	3013.9	-121.6	-58.7	-0.069197	-0.134845	-0.204042	-0.125012	0.015627984
Jun-06	5	1.667	3139.2	3077.2	3221.7	-144.5	-62	-0.07431	-0.010521	-0.084831	-0.005801	3.36562E-05
Sep-06	3	1.000	3339.7	3252.9	3412	-159.1	-86.8	-0.083096	-0.123691	-0.206787	-0.127757	0.016321901
				Anl Bgt:	781.53		**Avg:**	-0.063884	-0.015146	**-0.07903**	0.00	0.01017227
											Std Dev:	**0.1009**

Table 16. Performance Calculations for Program E.

Inspection of program data shows R_{EVM}'s ranging from -16.87 (Program A) to +7.29 percent (Program D), and standard deviations running from 8.06 (Program C) to 60.79 percent (Program D). With two exceptions, R_{CV} and R_{SV} values are negative, indicating program costs tend to grow and schedules tend to slow. Program B has no data (blank fields) for periods where program resets (re-baselines) occurred. Finally, it is noted that Program C is a recent start and has little more than half the amount of data points of the other programs.

2. Calculation of Portfolio Statistical Measures

Using the program statistical measures above, portfolio measures were calculated and are presented in Tables 17 through 21, below. Each table contains: a normalized alignment quarter, program deviation data, and the calculated co-variances between the programs. The bottom of each table contains the computed co-variance sums, averages, and correlation coefficients for each program pairing.

While not required for the analysis, the correlation coefficient is provided as a calculation check and informational purposes. A correlation coefficient of one means the paired programs move in perfect synchronization (pairings of a program to itself should be perfectly correlated), a negative one indicates that the programs move in perfectly opposite directions, and zero indicates no relationship between the pairings. An inspection of the computed correlation

coefficients indicates that although all the programs are physically similar in nature, their performances vary significantly from one another from period to period. For instance, inspection of Program A's correlation coefficients in Table 17 indicate that programs B and C are relatively uncorrelated with Program A (coefficients near zero), while Program E is fairly positively correlated, and Program D is fairly negatively correlated. All things being equal, a portfolio with Programs A and D would be less risky than other Program A pairings.

Align Qtr	R_{EVM}-R_{av} (A)	A with A	A with B	A with C	A with D	A with E
1Qtr04						
2Qtr04	0.19267710	0.03712447	0.01086064		-0.07571533	-0.00190915
3Qtr04	0.19551025	0.03822426	0.00633366		0.00117196	-0.00077332
4Qtr04	0.12638424	0.01597298			0.05675142	0.02758422
1Qtr05	-0.02062929	0.00042557	-0.00220040	-0.00154692	-0.00295093	-0.00057464
2Qtr05	0.15135537	0.02290845	0.00894614	-0.01348179	-0.00637630	
3Qtr05	-0.48924929	0.23936486	-0.00265132		0.05711153	0.02933758
4Qtr05	0.06764848	0.00457632		0.00884930	-0.04362437	0.00583715
1Qtr06	-0.29610631	0.08767895	-0.01545428	0.01583675	-0.40721897	0.03701682
2Qtr06	-0.06512646	0.00424146	0.00941172	-0.00065996	-0.01310991	
3Qtr06	0.13075270	0.01709627	-0.02191804		-0.12786696	-0.00075855
4Qtr06	0.00678320	0.00004601		-0.00049773		-0.00086660
	Co-var Sum:	0.46765958	-0.00667188	0.00849966	-0.56182785	0.09489352
	Co-var Avg:	0.04251451	-0.00083398	0.00141661	-0.05618279	0.01054372
	Corrl Coeff:	1	-0.04298435	0.08519885	-0.44819791	0.50700998

Table 17. Paired Co-variance Calculations for Program A.

Align Qtr	R_{EVM}-R_{av} (B)	B with A	B with B	B with C	B with D	B with E
1Qtr04						
2Qtr04	0.05636705	0.01086064	0.00317724		-0.02215027	-0.00055852
3Qtr04	0.03239552	0.00633366	0.00104947		0.00019419	-0.00012814
4Qtr04						
1Qtr05	0.10666399	-0.00220040	0.01137721	0.00799838	0.01525784	0.00297119
2Qtr05	0.05910688	0.00894614	0.00349362	-0.00526487	-0.00249005	
3Qtr05	0.00541916	-0.00265132	0.00002937		-0.00063260	-0.00032496
4Qtr05						
1Qtr06	0.05219166	-0.01545428	0.00272397	-0.00279138	0.07177636	-0.00652458
2Qtr06	-0.14451457	0.00941172	0.02088446	-0.00146443	-0.02909068	
3Qtr06	-0.16762969	-0.02191804	0.02809971		0.16393007	0.00097249
4Qtr06						
	Co-var Sum:	-0.00667188	0.07083506	-0.00152231	0.19679487	-0.00359252
	Co-var Avg:	-0.00083398	0.00885438	-0.00038058	0.02459936	-0.00059875
	Corrl Coeff:	-0.04298435	1	-0.05015509	0.43001121	-0.06308983

Table 18. Paired Co-variance Calculations for Program B.

Align Qtr	R_{EVM}-R_{av} (C)	C with A	C with B	C with C	C with D	C with E
1Qtr04						
2Qtr04						
3Qtr04						
4Qtr04						
1Qtr05	0.07498671	-0.00154692	0.00799838	0.00562301	0.01072654	0.00208880
2Qtr05	-0.08907374	-0.01348179	-0.00526487	0.00793413	0.00375250	
3Qtr05						
4Qtr05	0.13081307	0.00884930		0.01711206	-0.08435722	0.01128741
1Qtr06	-0.05348333	0.01583675	-0.00279138	0.00286047	-0.07355272	0.00668605
2Qtr06	0.01013347	-0.00065996	-0.00146443	0.00010269	0.00203986	
3Qtr06						
4Qtr06	-0.07337619	-0.00049773		0.00538406		0.00937434
	Co-var Sum:	0.00849966	-0.00152231	0.03901642	-0.14139104	0.0294366
	Co-var Avg:	0.00141661	-0.00038058	0.00650274	-0.02827821	0.00735915
	Corrl Coeff:	0.08519885	-0.05015509	1	-0.57681822	0.90483761

Table 19. Paired Co-variance Calculations for Program C.

Align Qtr	R_{EVM}-R_{av} (D)	D with A	D with B	D with C	D with D	D with E
1Qtr04						
2Qtr04	-0.39296487	-0.07571533	-0.02215027		0.15442139	0.00389371
3Qtr04	0.00599438	0.00117196	0.00019419		0.00003593	-0.00002371
4Qtr04	0.44903874	0.05675142			0.20163579	0.09800575
1Qtr05	0.14304585	-0.00295093	0.01525784	0.01072654	0.02046212	0.00398462
2Qtr05	-0.04212800	-0.00637630	-0.00249005	0.00375250	0.00177477	
3Qtr05	-0.11673299	0.05711153	-0.00063260		0.01362659	0.00699983
4Qtr05	-0.64486844	-0.04362437		-0.08435722	0.41585530	-0.05564348
1Qtr06	1.37524582	-0.40721897	0.07177636	-0.07355272	1.89130108	-0.17192214
2Qtr06	0.20129928	-0.01310991	-0.02909068	0.00203986	0.04052140	
3Qtr06	-0.97792979	-0.12786696	0.16393007		0.95634667	0.00567336
4Qtr06						
	Co-var Sum:	-0.56182785	0.19679487	-0.14139104	3.69598104	-0.10903206
	Co-var Avg:	-0.05618279	0.02459936	-0.02827821	0.3695981	-0.01362901
	Corrl Coeff:	-0.44819791	0.43001121	-0.57681822	1	-0.2222749

Table 20. Paired Co-variance Calculations for Program D.

Align Qtr	R_{EVM}-R_{av} (E)	E with A	E with B	E with C	E with D	E with E
1Qtr04						
2Qtr04	-0.00990854	-0.00190915	-0.00055852		0.00389371	0.00009818
3Qtr04	-0.00395537	-0.00077332	-0.00012814		-0.00002371	0.00001564
4Qtr04	0.21825678	0.02758422			0.09800575	0.04763602
1Qtr05	0.02785558	-0.00057464	0.00297119	0.00208880	0.00398462	0.00077593
2Qtr05						
3Qtr05	-0.05996448	0.02933758	-0.00032496		0.00699983	0.00359574
4Qtr05	0.08628657	0.00583715		0.01128741	-0.05564348	0.00744537
1Qtr06	-0.12501194	0.03701682	-0.00652458	0.00668605	-0.17192214	0.01562798
2Qtr06						
3Qtr06	-0.00580140	-0.00075855	0.00097249		0.00567336	0.00003366
4Qtr06	-0.12775720	-0.00086660		0.00937434		0.01632190
	Co-var Sum:	0.09489352	-0.00359252	0.0294366	-0.10903206	0.09155043
	Co-var Avg:	0.01054372	-0.00059875	0.00735915	-0.01362901	0.01017227
	Corrl Coeff:	0.50700998	-0.06308983	0.90483761	-0.2222749	1

Table 21. Paired Co-variance Calculations for Program E.

Although the average co-variances are the values to be used in subsequent calculations, an inspection of the correlation coefficients for comparison purposes is illuminating. The correlation coefficients range from a high of 0.90 to a low of negative 0.58. This range of values indicates that despite all five programs being naval aircraft acquisitions, the programs are not uniform in quarterly performance relative to each other. The range of correlation coefficient values indicates room for portfolio improvement exists.

3. Optimal Portfolio Weighting

In order to fully mirror the previous oil-sector stock portfolio example, the government program portfolio was analyzed using the same non-linear model to provide an optimal portfolio solution. Table 22 provides a summary of the values derived from program EVM data, used in the model.

							Co-variances		
	Bgt	**% Bgt**	R_{EVM}	σ_{EVM}	**A**	**B**	**C**	**D**	**E**
Prgm A	486.1	0.240	-0.168707	0.20619	0.4251500	-0.0008340	0.0014166	-0.0561830	0.0105437
Prgm B	432.93	0.214	0.0136173	0.09410	-0.0008340	0.0088544	-0.0003810	0.0245994	-0.0005990
Prgm C	185.48	0.092	-0.015775	0.08064	0.0014166	-0.0003810	0.0065027	-0.0282780	0.0073591
Prgm D	135.5	0.067	0.072933	0.60795	-0.0561830	0.0245994	-0.0282780	0.3696981	-0.0136290
Prgm E	781.53	0.387	-0.07903	0.10086	0.0105437	-0.0005990	0.0073591	-0.0136290	0.0101723
Total:	2021.5	1.00	**-0.06476**	**:Portfolio Wtd Avg**					

Table 22. Summary of Government Program Portfolio Statistics.

The plot of the risk and return efficient frontier values calculated from the non-linear model for an optimized government program portfolio is shown in Figure 5. The plot indicates that risk can be lowered and return improved up to the diagramed inflection point. R_{EVM} can be improved to -2.6 from an initial portfolio R_{EVM} of -6.476 percent and risk reduced from 6.95 to 5.02 percent. Stated in terms of percent improvement, optimization of the government portfolio improved the portfolio's R_{EVM} 59.9 percent and reduced portfolio risk 27.8 percent.

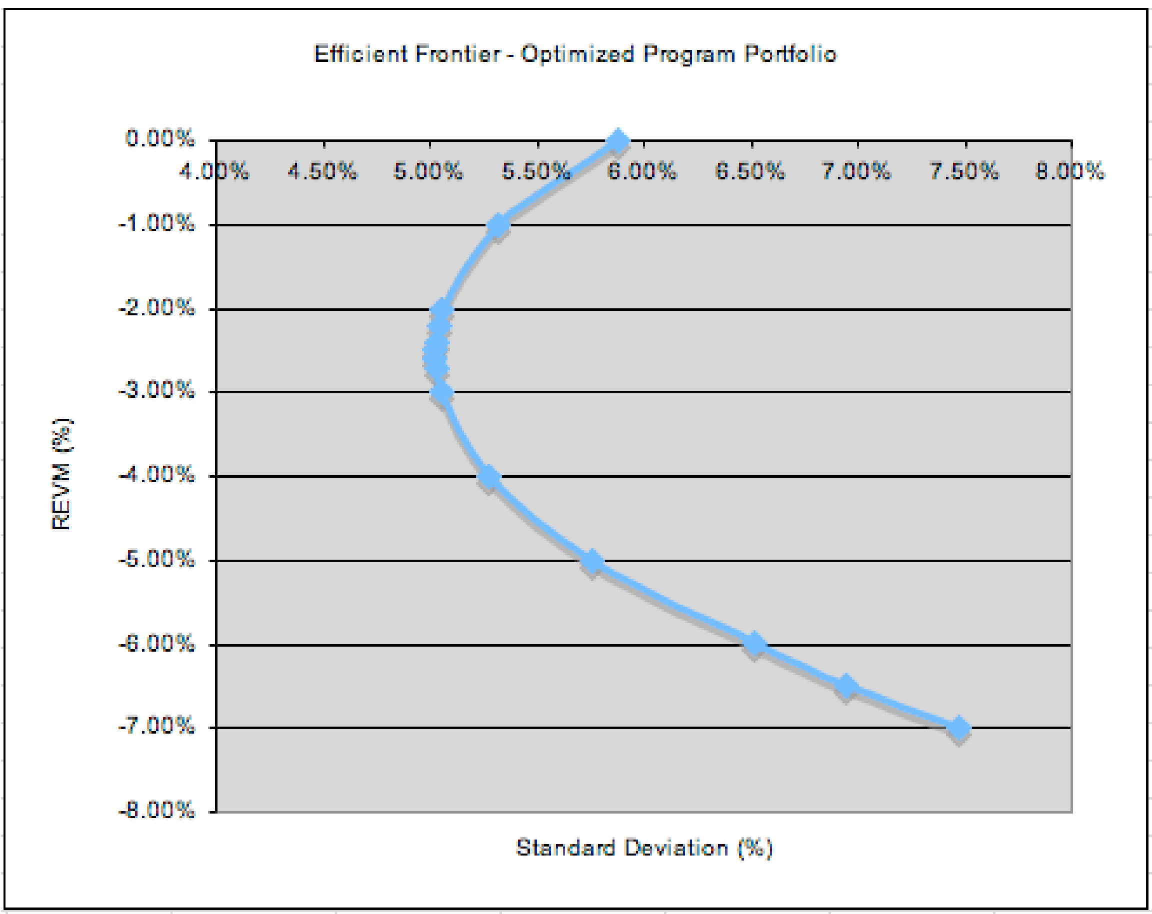

Figure 5. Optimum Program Portfolio Plot of R_{EVM} versus σ_{EVM}.

Optimizing the portfolio as above, results in changes to individual program funding levels as displayed in Table 23. The table provides the initial program budget, the optimized revised budget, the dollar amount of the change, the percentage change, and the initial and optimized program weights within the portfolio.

	Init Bgt	Rev Bgt	Bgt Chg	Bgt Chg %	Init Wt	Rev Wt	Wt Chg
Pgm A	486.1	267.4	-218.7	-44.98%	24.05%	13.23%	-10.82%
Pgm B	432.9	267.6	-165.3	-38.17%	21.41%	13.24%	-8.17%
Pgm C	185.5	1346.9	1161.4	626.11%	9.18%	66.63%	57.45%
Pgm D	135.5	139.5	4.0	2.94%	6.70%	6.90%	0.20%
Pgm E	781.5	0.0	-781.5	-100.00%	38.66%	0.00%	-38.66%
Total	2021.5	2021.5	0.0	0.00%	100.00%	100.00%	

Table 23. Optimized Portfolio Program Funding Levels and Weightings.

Inspection of the optimized portfolio highlights the shortcomings of the pure optimization of government program portfolios. For example, while selling 45 percent of a particular stock is straightforward, cutting Program A’s budget by 45 percent is not, for contractual, programmatic, and practical manufacturing reasons. Similarly, while purchasing large amounts of stocks is fairly direct, increasing the funding of a program by 626 percent will not instantly generate the planned return due to practical production expansion difficulties. Finally, while 626 percent more “cargo planes” and zero “jet fighters” might be financially efficient, it certainly would not be operationally desired or required. Accordingly, while an optimized program portfolio can be generated, the practical difficulties in implementing large changes in production, coupled with the operational undesirability of these changes, makes direct application of program portfolio optimization impractical.

B. THE CONSTRAINED EVM GOVERNMENT PORTFOLIO

While direct optimization is largely academic, constrained optimization, within the bounds of typical government portfolio financial manager tasking, is more practically oriented. As previously discussed, Department of Defense

financial managers are often tasked with managing portfolios of appropriation categories, not unlike the five-program portfolio considered by this research. Two typical portfolio constraints are: program-funding cannot be increased by moving funds from other portfolio programs, and that individual program-funding cannot be cut more than a specified percentage.

1. Calculation of Program Statistical Measures

The program performance measures calculated and displayed in Tables 12 through 16, above, are the same measures used in the constrained non-linear model.

2. Calculation of Portfolio Statistical Measures

The portfolio statistical measures calculated and displayed in Tables 17 through 21 and summarized in Table 22, above, are the same measures used in the constrained non-linear model.

3. Constrained Optimal Portfolio Weighting

Six constrained portfolio examples are presented. Overall portfolio funding reduction constraints of three, five, and seven percent were analyzed, each further constrained with maximum program cuts equal to either three-times or four-times the overall portfolio reduction. Constrained analysis results for a portfolio-funding cut of three percent and individual program cuts of no more than nine and twelve percent are presented in Figures 6 and 7, and the accompanying funding distributions and weightings in Tables 24 and 25.

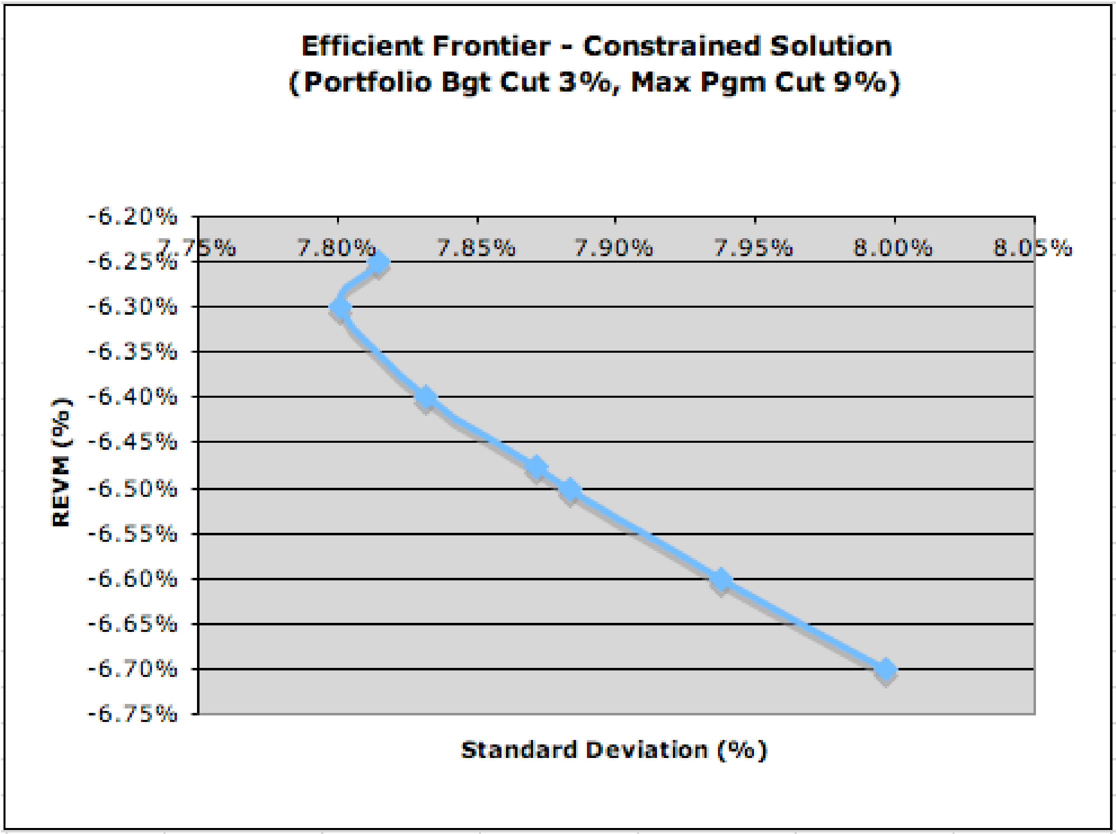

Figure 6. Constrained 3% Overall Portfolio Funding Cut, 9% Maximum Program Cut, Portfolio Plot of R_{EVM} versus σ_{EVM}.

	Init Bgt	Rev Bgt	Bgt Chg	Bgt Chg %	Init Wt	Rev Wt	Wt Chg
Pgm A	486.1	442.3	-43.8	-9.01%	24.05%	22.56%	-1.49%
Pgm B	432.9	432.9	0.0	0.00%	21.41%	22.08%	0.67%
Pgm C	185.5	185.5	0.0	0.00%	9.18%	9.46%	0.28%
Pgm D	135.5	126.8	-8.7	-6.42%	6.70%	6.46%	-0.24%
Pgm E	781.5	773.4	-8.1	-1.04%	38.66%	39.44%	0.78%
Total	2021.5	1960.9	-60.6	-3.00%	100.00%	100.00%	

Table 24. Constrained 3% Overall Portfolio Funding Cut, 9% Maximum Program Cut, Portfolio Program Funding Levels and Weightings.

The Figure 6 plot indicates that risk can be lowered and return improved up to the diagramed inflection point. Specifically, R_{EVM} can be improved to -6.3 from an initial portfolio R_{EVM} of -6.476 percent and risk reduced from 7.87 to 7.80 percent. Stated in terms of percent improvement, optimization of the constrained portfolio improved the portfolio's R_{EVM} 2.72 percent and reduced portfolio risk 0.89 percent. Recommended funding changes are found in Table 24.

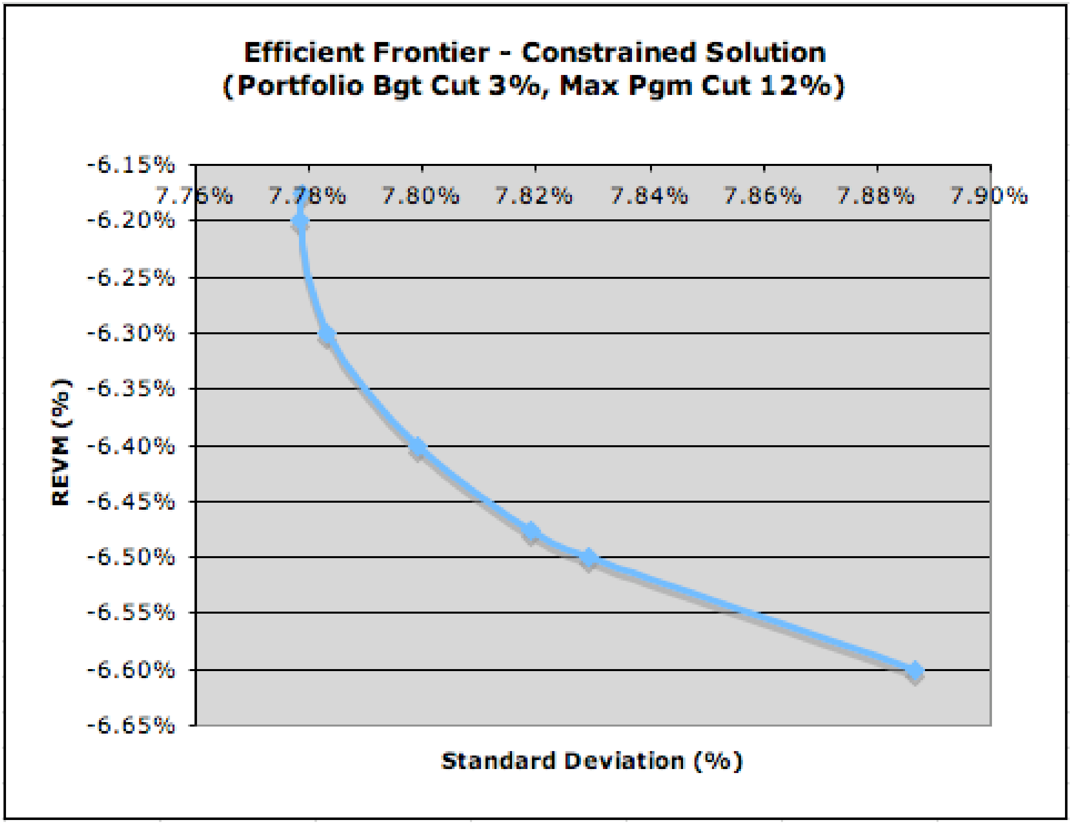

Figure 7. Constrained 3% Overall Portfolio Funding Cut, 12% Maximum Program Cut, Portfolio Plot of R_{EVM} versus σ_{EVM}.

	Init Bgt	Rev Bgt	Bgt Chg	Bgt Chg %	Init Wt	Rev Wt	Wt Chg
Pgm A	486.1	429.1	-57.0	-11.73%	24.05%	21.88%	-2.17%
Pgm B	432.9	432.9	0.0	0.00%	21.41%	22.08%	0.67%
Pgm C	185.5	185.5	0.0	0.00%	9.18%	9.46%	0.28%
Pgm D	135.5	131.8	-3.7	-2.73%	6.70%	6.72%	0.02%
Pgm E	781.5	781.5	0.0	0.00%	38.66%	39.86%	1.20%
Total	2021.5	1960.8	-60.7	-3.00%	100.00%	100.00%	

Table 25. Constrained 3% Overall Portfolio Funding Cut, 12% Maximum Program Cut, Portfolio Program Funding Levels and Weightings.

The Figure 7 plot indicates that R_{EVM} can be improved to -6.2 from an initial portfolio R_{EVM} of -6.476 percent and risk reduced from 7.82 to 7.78 percent. In percent improvement terms, optimization of the constrained portfolio improved the portfolio's R_{EVM} 4.26 percent and reduced portfolio risk 0.52 percent. Recommended funding changes are found in Table 25.

Constrained analysis results for a portfolio-funding cut of five percent and individual program cuts of no more than fifteen and twenty percent are presented in Figures 8 and 9, and the accompanying funding distributions and weightings in Tables 26 and 27.

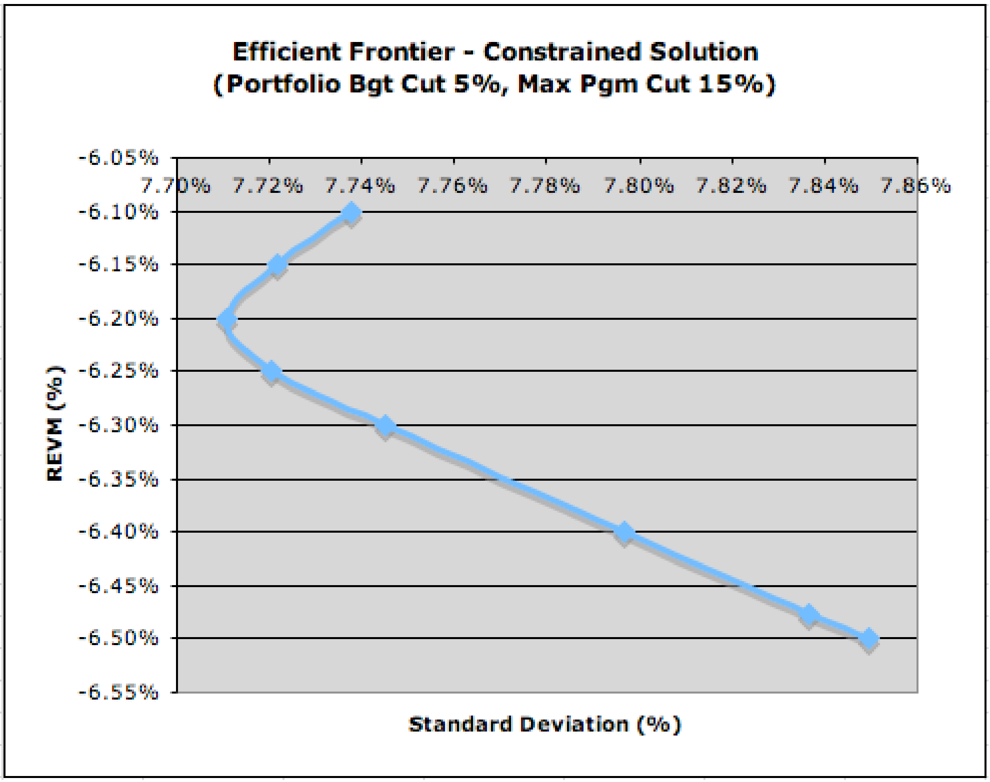

Figure 8. Constrained 5% Overall Portfolio Funding Cut, 15% Maximum Program Cut, Portfolio Plot of R_{EVM} versus σ_{EVM}.

	Init Bgt	Rev Bgt	Bgt Chg	Bgt Chg %	Init Wt	Rev Wt	Wt Chg
Pgm A	486.1	413.2	-72.9	-15.00%	24.05%	21.52%	-2.53%
Pgm B	432.9	432.9	0.0	0.00%	21.41%	22.54%	1.13%
Pgm C	185.5	185.5	0.0	0.00%	9.18%	9.66%	0.48%
Pgm D	135.5	117.9	-17.6	-12.99%	6.70%	6.14%	-0.56%
Pgm E	781.5	770.9	-10.6	-1.36%	38.66%	40.14%	1.48%
Total	2021.5	1920.4	-101.1	-5.00%	100.00%	100.00%	

Table 26. Constrained 5% Overall Portfolio Funding Cut, 15% Maximum Program Cut, Portfolio Program Funding Levels and Weightings.

The Figure 8 plot indicates that R_{EVM} can be improved to -6.2 from an initial portfolio R_{EVM} of -6.476 percent and risk reduced from 7.84 to 7.71 percent.

In percent improvement terms, optimization of the constrained portfolio improved the portfolio's R_{EVM} 4.26 percent and reduced portfolio risk 1.61 percent. Recommended funding changes are found in Table 26. While the reduction in risk is small, it is quantifiable.

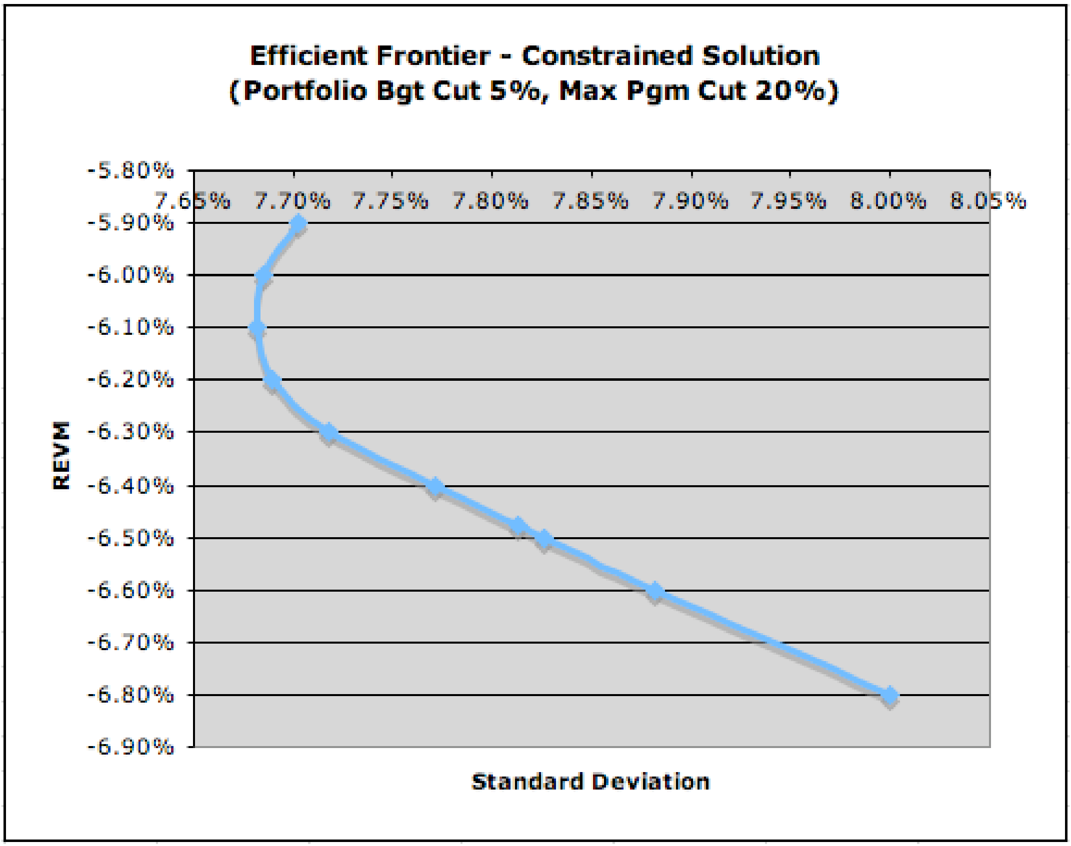

Figure 9. Constrained 5% Overall Portfolio Funding Cut, 20% Maximum Program Cut, Portfolio Plot of R_{EVM} versus σ_{EVM}.

	Init Bgt	Rev Bgt	Bgt Chg	Bgt Chg %	Init Wt	Rev Wt	Wt Chg
Pgm A	486.1	398.6	-87.5	-18.00%	24.05%	20.75%	-3.30%
Pgm B	432.9	432.9	0.0	0.00%	21.41%	22.54%	1.13%
Pgm C	185.5	185.5	0.0	0.00%	9.18%	9.66%	0.48%
Pgm D	135.5	121.9	-13.6	-10.04%	6.70%	6.35%	-0.35%
Pgm E	781.5	781.5	0.0	0.00%	38.66%	40.70%	2.04%
Total	2021.5	1920.4	-101.1	-5.00%	100.00%	100.00%	

Table 27. Constrained 5% Overall Portfolio Funding Cut, 20% Maximum Program Cut, Portfolio Program Funding Levels and Weightings.

The Figure 9 plot indicates that R_{EVM} can be improved to -6.1 from an initial portfolio R_{EVM} of -6.476 percent and risk reduced from 7.81 to 7.68 percent. In percent improvement terms, optimization of the constrained portfolio improved the portfolio's R_{EVM} 5.81 percent and reduced portfolio risk 1.67 percent. Recommended funding changes are found in Table 27.

Constrained analysis results for a portfolio-funding cut of ten percent and individual program cuts of no more than thirty and forty percent are presented in Figures 10 and 11, and the accompanying funding distributions and weightings in Tables 28 and 29.

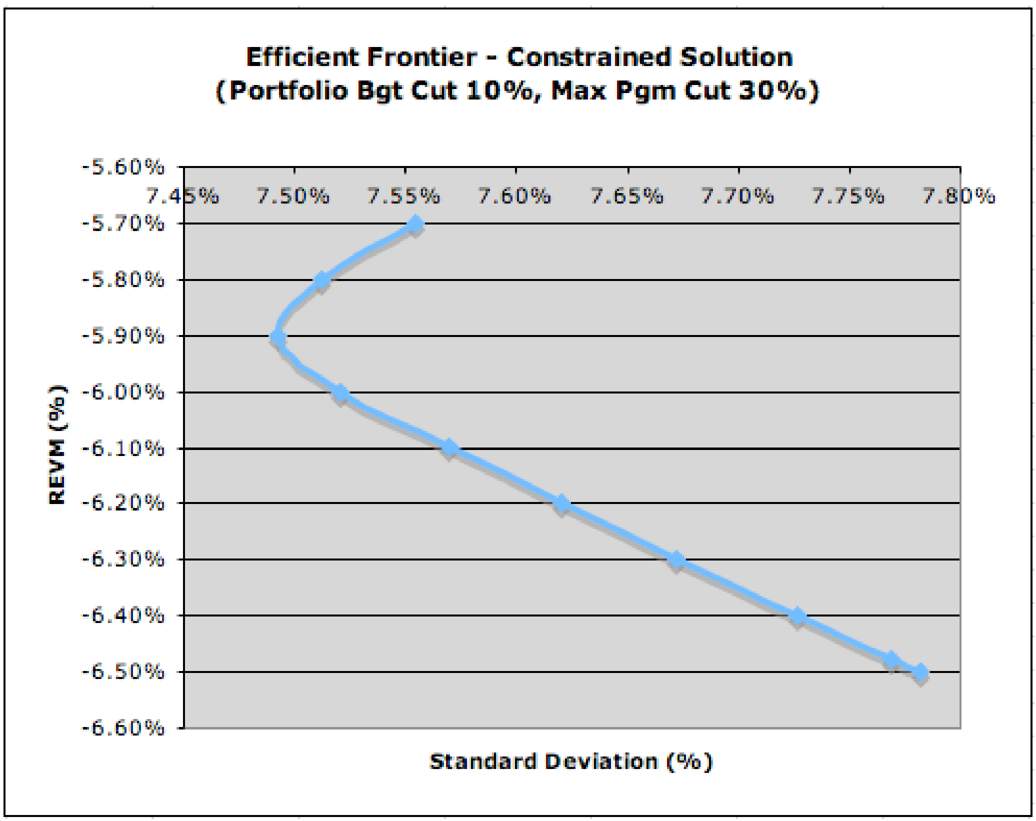

Figure 10. Constrained 10% Overall Portfolio Funding Cut, 30% Maximum Program Cut, Portfolio Plot of R_{EVM} versus σ_{EVM}.

	Init Bgt	Rev Bgt	Bgt Chg	Bgt Chg %	Init Wt	Rev Wt	Wt Chg
Pgm A	486.1	340.3	-145.8	-29.99%	24.05%	18.70%	-5.35%
Pgm B	432.9	432.9	0.0	0.00%	21.41%	23.80%	2.39%
Pgm C	185.5	185.5	0.0	0.00%	9.18%	10.19%	1.01%
Pgm D	135.5	99.5	-36.0	-26.57%	6.70%	5.47%	-1.23%
Pgm E	781.5	761.2	-20.3	-2.60%	38.66%	41.84%	3.18%
Total	2021.5	1819.4	-202.1	-10.00%	100.00%	100.00%	

Table 28. Constrained 10% Overall Portfolio Funding Cut, 30% Maximum Program Cut, Portfolio Program Funding Levels and Weightings.

The Figure 10 plot indicates that R_{EVM} can be improved to -5.9 from an initial portfolio R_{EVM} of -6.476 percent and risk reduced from 7.77 to 7.49 percent. In percent improvement terms, optimization of the constrained portfolio improved the portfolio's R_{EVM} 8.89 percent and reduced portfolio risk 3.56 percent. Recommended funding changes are found in Table 28.

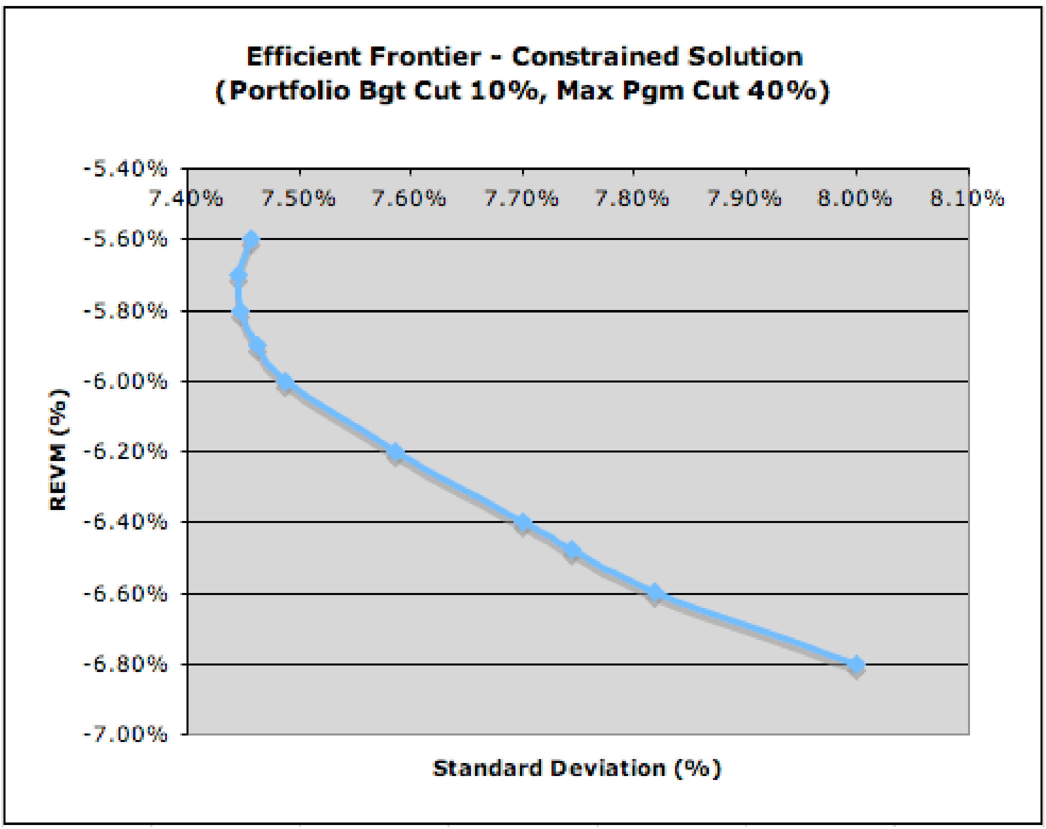

Figure 11. Constrained 10% Overall Portfolio Funding Cut, 40% Maximum Program Cut, Portfolio Plot of R_{EVM} versus σ_{EVM}.

	Init Bgt	Rev Bgt	Bgt Chg	Bgt Chg %	Init Wt	Rev Wt	Wt Chg
Pgm A	486.1	312.4	-173.7	-35.73%	24.05%	17.17%	-6.88%
Pgm B	432.9	432.9	0.0	0.00%	21.41%	23.80%	2.39%
Pgm C	185.5	185.5	0.0	0.00%	9.18%	10.19%	1.01%
Pgm D	135.5	107.0	-28.5	-21.03%	6.70%	5.88%	-0.82%
Pgm E	781.5	781.5	0.0	0.00%	38.66%	42.96%	4.30%
Total	2021.5	1819.3	-202.2	-10.00%	100.00%	100.00%	

Table 29. A Constrained 10% Overall Portfolio Funding Cut, 40% Maximum Program Cut, Portfolio Program Funding Levels and Weightings.

The Figure 11 plot indicates that R_{EVM} can be improved to -5.7 from an initial portfolio R_{EVM} of -6.476 percent and risk reduced from 7.74 to 7.45 percent. In percent improvement terms, optimization of the constrained portfolio improved the portfolio's R_{EVM} 11.98 percent and reduced portfolio risk 3.85 percent. Recommended funding changes are found in Table 29. A summary of the various constrained portfolios and their respective improvements in risk and return is presented in Table 30.

Port Cut (%)	Pgm Cut (%)	Chg in Rtn (%)	Chg in Risk (%)
3	9	2.72	-0.89
3	12	4.26	-0.52
5	15	4.26	-1.61
5	20	5.81	-1.67
10	30	8.89	-3.56
10	40	11.98	-3.85

Table 30. Summary of Constrained Portfolio Optimization Results.

The overall results of the constrained portfolio analysis indicate that both risk and return can be quantitatively improved using financial portfolio analysis when making required portfolio funding cuts. Since R_{EVM} represents the rate of change (return) of both cost and schedule variances,[2] an improvement in R_{EVM} represents an improvement in overall portfolio CV and SV performance. Further,

[2] Remember that the "variances" discussed in EVM are not the same as the mathematical variances of statistics, but are simply the difference between planned and actual values.

these improvements can be realized with an accompanying reduction in the risk (standard deviation) of the portfolio up to a minimum risk inflection point.

An examination of the constrained EVM portfolio R_{EVM} versus σ_{EVM} plot reveals two trends. First, the inflection points of the plotted efficient frontiers become less sharp, the larger the allowed individual program cuts become relative to the overall portfolio cut. The “blunter” the efficient frontier curve, the greater the improvement of R_{EVM} from its initial portfolio value, since the efficient frontier curve takes longer to reach a vertical inflection point. For the same reason, a “blunter” curve produces smaller incremental improvements in portfolio risk. In cases where the efficient frontier curve is already “blunt,” increases in the maximum individual cut percentage relative to the overall portfolio cut can result in less overall risk reduction compared to lower relative percentages.

Second, the closer the maximum individual program cut percentage is to the overall portfolio percentage cut, the smaller the feasible efficient frontier becomes. In other words, the closer the overall portfolio cut and maximum individual program percentage cuts are to one another, the smaller the feasible segment of the efficient frontier curve becomes. This can be seen when comparing Figures 6 and 7, 8 and 9, and 10 and 11. While the efficient frontier curves are different in each figure, the feasible portion of the curve shrinks from the top, down. At the extreme, where the overall portfolio cut and maximum individual program cuts are equal, the only feasible solution is the point equal to the initial portfolio’s R_{EVM} and risk.

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V. RECOMMENDATIONS AND CONCLUSION

A. APPLICATION OF EVM-BASED PORTFOLIO ANALYSIS

This research has successfully demonstrated an application of financial portfolio analysis techniques to a sample government acquisition program portfolio using Earned Value Management data as a proxy for "stock price." Where changes in stock price over time allow a rate of return to be calculated for a stock, changes in schedule and cost over time allow an "EVM rate of return" (R_{EVM}) to be computed. The direct application of a non-linear portfolio optimization model using R_{EVM} produced an optimally weighted program portfolio of little practical value. However, a modified non-linear portfolio optimization model accounting for "real-world" portfolio manager constraints, produced useful portfolio weighting recommendations suitable for further consideration and possible implementation. The application of EVM-based government program portfolio analysis has several advantages and limitations.

1. Advantages of EVM-based Portfolio Analysis

EVM-based portfolio analysis presents four distinct advantages: it is a quantitative method, it is aligned with program performance, it is readily scaleable, and it addresses a practical need.

Government financial management decision-makers generally prefer to base decisions on quantitative evaluation methods. The analysis of independently gathered EVM data in accordance with accepted financial portfolio analysis practices allows a quantitative comparison of portfolio risk and return. The ability to indicate that a proposed action is expected to increase portfolio return by a quantifiable percentage, while reducing portfolio risk by quantifiable percentage, is preferable to more generalized methods. A quantitative approach also has the potential to reduce perceptions that higher-level government financial manager portfolio decisions are made arbitrarily.

Portfolio analysis based on component program EVM data directly links the government's primary program performance measuring system, the EVM System, to financial decisions regarding the overall portfolio. Because EVM data provide program cost and schedule performance measures used by the program manager, basing portfolio analysis on the same measures is organizationally consistent. Since programs are assessed against planned schedule and cost at the program level, the incorporation of schedule and cost rates of change within the R_{EVM} metric maintains a program performance linkage at the higher level of program portfolio management. The use of historical EVM data, as compared to historical stock data, has the added advantage of being a fairly reliable indicator of future performance. While historical stock prices are the best indication of future prices, the correlation between past and future is notoriously variable. The EVM System, on the other hand, has been shown to be fairly predictive in its ability to forecast future cost (Christensen et al., 2002).

The nature of portfolio statistical analysis is applicable to a portfolio of programs, a portfolio of portfolios, or any mixture of the two. This characteristic makes portfolio analysis broadly scaleable (Reilly et al., 2003). For example, aircraft programs with numerous contracts for the power-plant, radar, and airframe can be formed into an overall "aircraft type" portfolio, and the resulting "aircraft type" portfolio statistics used within a larger "fixed-wing aircraft" portfolio. This "scalability" makes portfolio analysis at any level manageable and directly relevant to the decisions made at that level.

Finally, the portfolio analysis performed in this research addresses a practical need. Government financial managers are often tasked to identify programs as potential funding cut candidates. The relatively distant relationship of the government portfolio financial manager with the various programs being financially managed, makes informed decision-making challenging. As a tool, EVM-based Financial Portfolio Analysis, allows the government financial manager to make rational, financially based, portfolio recommendations. While this analysis tool is by no means exclusive, meaning that other considerations (for instance political or operational requirements) must still be considered, it

does give the government financial manager an additional tool with which to guide decisions. The recommendations gleaned from program portfolio analysis can also be fed back into the defense planning, programming, and budgeting processes as additional input for consideration when determining future program mixes.

2. Limitations of EVM-based Portfolio Analysis

While promising, the EVM-based portfolio analysis examined in this research has several important limitations. First and foremost, EVM-based portfolio analysis is simply an additional analytical tool, not a solution. EVM-based portfolio analysis should not be used as a stand-alone method for financial program portfolio decisions, but in conjunction with current techniques, overall political and financial guidance, and consultation with program managers to facilitate fully informed decision-making. Some additional EVM-based portfolio analysis limitations include: alignment with portfolio manager's short-term goals, limited numbers of programs with EVM data, the granularity of high-level EVM data, and implementation hurdles.

While the incorporation of program performance within portfolio analysis is an overall advantage, the government portfolio financial manager has short-term expenditure goals that may not be fully served by the portfolio analysis model presented. Specifically, government portfolio financial managers are charged with ensuring the timely annual expenditure of portfolio funds. The R_{EVM} based model takes into account schedule variances, which although ultimately affecting overall program cost, may, in the short-term have less impact on expenditures. For example, a program with an increasing negative EVM schedule variance (increasingly falling behind schedule) but within budget, and a program with an increasing negative cost variance trend (increasingly over-budget) but on schedule, are interchangeable within the analysis, but have different short-term expenditure profiles. The increasingly behind schedule program expends no money in the short-term because the schedule slippage defers costs to the

future, while the increasingly over-budget program is expending funds in the present. The optimized rate of return assumes both these “expenditures” occur in the present, decreasing the overall fidelity of the model as compared to the portfolio manager’s short-term goal.

Another shortcoming with R_{EVM} based portfolio analysis is that EVM data are only required for certain programs within a typical government portfolio. Many portfolios include programs in the life-cycle maintenance phase, where EVM data are not required. Even programs within the acquisition process may not require EVM data be collected due to dollar threshold requirements or contract type. This research is silent on methods to combine EVM and non-EVM programs within the portfolio analysis framework.

The EVM data used in this research were reported in different months, for different periods, for different programs. Although the EVM data were generally quarterly data, the inconsistencies between programs, and the relatively long period, made the alignment of program data for correlation purposes difficult. Any lack of alignment affects the resultant correlations (co-variance calculations) and overall risk measurement. Access to more frequently reported and aligned EVM data would certainly improve overall portfolio analysis.

Finally, the requirements for data collection, normalization, alignment, and calculation for this research’s five-program portfolio were fairly rigorous and time-consuming. The routine application of EVM-based program portfolio analysis would require a significant initial investment in process engineering, managerial time, and information technology support to realize consistent, broader benefits.

B. POTENTIAL FOR ADDITIONAL RESEARCH

Potential areas for additional research include: the conduct of a budgeting comparative method study; the identification of additional, potentially broader metrics with which to conduct financial portfolio analysis on non-acquisition programs; the potential application of portfolio analysis within requirements

generation planning; and research into additional potential corollaries between accepted financial market models and the proposed EVM-based portfolio approach.

1. Budgeting Comparative Method Study

The conduct of a study comparing current expenditure rate methods and the EVM-based portfolio analysis method demonstrated in this research in order to determine which method generates superior recommendations. The lack of access to historical expenditure data precluded comparisons during the course of this research. If the results of the contemplated study indicate that both methods generate similar recommendations, the simpler method would likely be favored.

2. Alternate Portfolio Analysis Measures

The identification of additional portfolio-specific metrics with which to conduct financial portfolio analysis of government non-acquisition portfolios would be beneficial in extending the applicability of this research. A potential example might be the development of an Operations and Maintenance (O&M) appropriations VM-like variance measure which could be used to conduct financial portfolio analysis of O&M portfolios. Recommendations on how portfolios using alternate measures might be combined in order to conduct quantitative analysis of portfolios containing both acquisition and life-cycle maintenance platforms could be pursued.

3. Portfolio Analysis in Support of Requirements Planning

While this research concentrated on combining existing EVM data and financial portfolio analysis as an additional practical tool for government portfolio managers, the portfolio analysis approach could be much more broadly applied. Additional research into the application of portfolio analysis during requirements definition has the potential to add a powerful analytical tool at an early stage where overall life-cycle costs are often locked-in by programmatic choices. A

suggested potential application might be to replace the rate of return value with an operational objective such as enemy attrition. Weapons systems that produce enemy attrition might then be correlated by how often they are purchased or used together, and enemy attrition "optimized" using the portfolio analysis techniques demonstrated in this research.[3]

4. Applications of other Financial Models to EVM-based Analysis

Finally, within the private financial sector, portfolio analysis is intertwined with several other financial models. For instance, in stock valuation, the Capital Asset Pricing Model (CAPM) often provides the returns used in portfolio theory analysis. Further research exploring potential corollaries between the CAPM within an EVM-based approach might further illuminate potentially useful relationships. Alternatives to the CAPM, such as consumption betas or Arbitrage Pricing Theory (APT) could also be explored.[4]

[3] This application presented by Professor Nayantara Hensel during class portfolio analysis discussions at the Naval Postgraduate School, Monterey.

[4] From thesis review discussions with Professor Nayantara Hensel.

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